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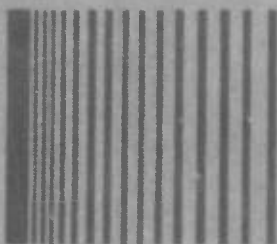


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# THE SHOCK AND VIBRATION DIGEST

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### THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research Laboratory  
Washington, DC 20375  
(202) 767-2220

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Dr. R.L. Eshleman  
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# SVIC NOTES

Not long ago I attended a DOD/Industry Technical Information Conference. Appropriately, the theme was "Improving DOD/Industry Technical Information Exchange." I listened with interest to the excellent presentations by industry and government speakers as they addressed the requirements and resources for DOD technical and management planning information, and I participated in some of the work group sessions organized to examine ways of improving the exchange of such information. The conference was well organized and well received. I am sure that those who participated now have a better understanding of the problems of information transfer and a greater knowledge of the resources available to them. In fact, many of the participants from both industry and government were amazed to learn about the number and nature of these information resources. They simply did not know that many of them existed.

In my opinion, there are two fundamental problems that impede the effective transfer of information and both of them are related to awareness. First of all, many individuals and a number of organizations do not recognize the value of accessing current information to support their own missions or goals. The word needs to be spread that information is power and that information promotes success, no matter whether success is measured in terms of profit or accomplishment. Secondly, many people are not aware that there is a lot of potential information support out there, or perhaps they do not know how to obtain that support. In this connection, we at the SVIC have been very much concerned with the promotion of awareness, particularly in our own technical community.

As we begin the 15th year of publication of this Digest, I would like to have the readers contribute to awareness on a broader basis. To be sure, if shock, vibration or other dynamics problems are your concern, the SVIC is the place to come. But, if you are looking for information in other technical areas, there are many other sources which can serve you well. How can one find out about these sources and how to use them? I suggest that there are many ways to do this, but consider two approaches that are very fundamental and often overlooked. First, call one or more of your friends or associates. Frequently, they can tell you how they have obtained similar information and what the sources were. Second, call an information source that you know, like SVIC, even though you know the information you seek is not in their field. If they are active within the information community, they can usually tell you about similar resources in other fields and how you can reach them. In any event, in any search for information, do not give up easily. Persist in your efforts. There is usually more than one way to get the information, and persistence pays off. The results can be rewarding.

As always, our particular concern is to serve the shock and vibration community to the best of our ability. So, once again I solicit your advice on ways to improve the Digest and other SVIC services. Drop me a line or give me a call if you have any ideas. My best wishes to all readers for a successful 1983.

H.C.P.

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# EDITORS RATTLE SPACE

## ENGINEERS IN THE AGE OF HIGH TECHNOLOGY

It would seem that the age of "high technology" is upon us. Apparently the continued innovations in the computer industry have fostered public awareness because in almost everything you read there is some reference to "high technology." There is even a new magazine called High Technology. Interestingly most of this technology has been around for more than 20 years but few individuals have made use of it.

I see this era of "high technology" as an excellent opportunity for the engineering profession. Developers of new processes and hardware should become more interested in using the finesse of computer simulation rather than the brute force trial-and-error methods that have been so common in the past. Engineers will be given a chance to use the tools of optimization and synthesis rather than accept solutions that could result in inefficient equipment. Mathematical analysis techniques will be used more frequently to check equipment trains and other complicated electro-mechanical systems.

Many problems involving obsolete equipment and facilities face the industrial world in the next decade. The use of "high technology" should provide efficient and cost effective solutions. It is now the responsibility of engineers to publicize their methods and solutions and to successfully apply what has been available for a long time. It will be the responsibility of managers and developers to accept the higher costs of engineering. However, the rewards of advanced engineering will far outweigh engineering-oriented costs.

R.L.E.

## TEXTBOOKS AND PERIODICAL LITERATURE IN ACOUSTICS

V.R. Miller\*

**Abstract.** *This paper presents a review of available textbooks on acoustics. The books are arranged to show the wealth of information that exists and the various aspects of acoustics, from theoretical considerations to practical and experimental applications. Periodical literature is also included.*

The feature article in the January, 1982, issue of the DIGEST dealt with a survey of textbooks in the field of vibration [1]. This article contained a list of available books and described their coverage of the various aspects of vibration engineering. The present article deals with texts in acoustics. Contents range from mathematical and theoretical to practical and experimental. Some deal with basics; others are in handbook form for the practitioner in industry.

The information available covers many areas and will undoubtedly grow as the current state of technology is incorporated into textbooks and special purpose books. This article is organized into the following categories: basic references, specialized texts, and periodicals and journals.

### BASIC REFERENCES

The serious noise control engineer or acoustician must understand not only dynamics, physics, mathematics, statistics, and signal processing but also the basics of acoustics. Morse and Ingard [12] cover generation, propagation, absorption, reflection, and scattering of compressional waves in fluid media. They also describe distortion of these waves by thermal and viscous effects and their coupling during vibration through walls and transmission through panels. Moving media, nonlinear effects, plasma acoustics, and the interaction of sound with light are also included. A book by Skudrzyk [27] on the theoretical aspects of acoustics is not recommended for the casual reader.

A relatively new analytical tool for the noise control engineer is statistical energy analysis (SEA). This concept is the subject of a comprehensive book by Lyon [11]; he introduces the reader to basic concepts and general procedures and explains such fundamentals as mode counts, loss factors, and coupling loss factors. He formulates the SEA model in terms of input powers and responses in terms of energies. Lyon discusses the inherent limitations of SEA as well as techniques used to overcome these limitations. He covers both the theoretical basis for SEA and applications to complex dynamic systems.

Junger and Feit [36] describe the relationship between acoustics and vibration by using servoloops with fluid-structure feedback. Other topics include Green's function, Helmholtz's integral equation, and the Sommerfield radiation condition. Another text that deals with the interaction of sound and structure began as a monograph but has been expanded by Heckl and Ungar [2]. Physical phenomena and principles of acoustics are covered, as is the sound radiation of structures.

Other standard reference texts on theory and fundamentals include Kinsler and Frey [4], Hueter and Bolt [20], and the classic work by Rayleigh [13]. Seto [17] used a problem solving approach to introduce the basics of acoustics. Meyer and Neumann [39] used detailed descriptions to help the novice become familiar with acoustics. Other textbooks are listed in Table 1.

Table 1. References Dealing with Theory and Fundamentals	
	References
Basic Textbooks	2 thru 39

\*5331 Pathview Drive, Huber Heights, Ohio 45424

## SPECIALIZED TEXTS

As more people have become concerned with the problem of noise, specialized topics in acoustics have become important. These specializations are grouped into several general categories in the discussion that follows.

**Instrumentation/measurement/analysis/testing.** Data analysis is one specialized area that has grown by an order of magnitude in the past decade. One reason is that inexpensive digital computers can process data quickly; in addition, new modeling concepts are constantly being developed. Available texts are listed in Table 2.

Table 2. Specialized Texts	
Topic	References
Instrumentation/Measurement/ Analysis/Testing	40 thru 69
Architectural	70 thru 98
Hearing Conservation/ Audiology	99 thru 121
Sonic Fatigue	122 thru 125
Underwater Acoustics	126 thru 133
Music	134 thru 139
Materials	140 thru 142
Handbooks/Guides	143 thru 177
Dictionary/Bibliographies	178 thru 182

Two experts in the field, Bendat and Piersol, have written several books [55, 66, 69], including an authoritative text [69] and, more recent, a text that supplements data processing procedures [66]. Bendat and Piersol consider random data, Fourier transforms, physical system response, spectral and correlation functions and their relationship, partial coherence, and cross correlation. Newland [67] has written an excellent discussion on digital stochastic analysis and random vibration. Individuals with a serious interest in signal analysis will be interested in the Papoulis text [53], which contains discussions of digital and

analog systems and signals; filtering operations; Fourier integrals, series, and sampling theory; windows; frequency modulation; band limited functions; and transformation properties. Correlation, spectral density functions, input/output relationships, and data smoothing and estimation are also described.

The book by Davenport and Root [49] is one of the best available references on random signals and noise. The authors present the fundamentals of probability and statistical detection from an engineering viewpoint and provide material on correlation functions, sampling considerations, random variables, and averages. However, they do not address such applications as noise source identification techniques. Another text by Schwartz and Shaw [65] contains a good introduction to signal processing. It covers such statistical and mathematical concepts associated with computing power spectral density as windows, smoothing, and variability. Beranek's book [40] is a good reference source on using measuring systems to obtain acoustic data. The two paperbacks by Broch [41, 44] are also oriented toward obtaining data.

The noise measurement book of Peterson and Gross [45] has been published in many editions. Of value to those who must take noise measurements, it describes measuring instruments and their use, proper equipment selection, and interpretation of measurements.

**Architectural.** The deleterious effects of noise from construction techniques is of interest in many situations, from poor acoustics in an auditorium to excessive noise from a lawn mower. Many books are concerned with architectural acoustics. Kuttruff [80] has investigated the physical properties of a sound field in a room and the subjective response of a listener. He provides general guidelines on reverberation time control and discusses acoustic modeling. Table 2 lists other texts on architectural acoustics, one of which [98] emphasizes the relationships of successful applications, requirements for such mechanical services as plumbing and heating, and concepts of building siting for noise control.

Government agencies consider the problem of sound control construction important enough to have issued several texts on the subject [70, 71, 77, 83, 87]. Industry has also contributed to the open literature [90].

One of the best books on architectural acoustics is that by Knudsen and Harris [88]. A good reference book it is devoted primarily to fundamentals but also includes information on sound absorbing materials, ventilating system noise, auditoriums, and room design. Design information is scattered throughout the book.

**Hearing conservation/audiology.** No one knows how many of the stress-induced diseases of modern society are exacerbated by rising noise levels. Noise damage to hearing is a subtle process; its immediate effects are not necessarily indicative of the ultimate results of exposure. As a result hearing conservation, speech, audiology programs, and deafness have been stressed over the years. Some texts are quite old [107, 109-112].

Experts from the Canadian Acoustical Association recently prepared a book to increase public awareness to environmental noise problems [119] and noise legislation. Sataloff and Michael [113] have described the physiology of hearing, causes of deafness, hearing loss, audiograms, and hearing tests; the information is written for the layman rather than the expert or practitioner. Curves representing different risk curves for noise and different noise levels are illustrated in the book by Burns and Robinson [120]. They show the association between temporary threshold shift and hearing deterioration attributed to industrial noise exposure. Related texts on hearing conservation are listed in Table 2.

**Acoustic fatigue.** Since the 1950s acoustic fatigue has emerged as a result of the high noise levels associated with jet engines. Few textbooks are devoted to this area, however. The text edited by Richards and Mead [123] contains information ranging from introductory concepts to practical applications of noise, including the consequences of fatigue in aircraft. They also discuss such acoustic test facilities as reverberation chambers, anechoic rooms, jet engine test cells, and jet engine open stands. Factors that affect fatigue such as endurance limit, fatigue strength, and corrosion as well as cumulative fatigue damage theories have been discussed by Collins [125]. The results of an international conference sponsored by the Air Force Materials Laboratory have been published [122].

**Underwater acoustics.** The number of texts shown in Table 2 is by no means a complete list of books

on the transmission of sound waves through water. Fundamentals are given in several texts [127, 129, 133]; others are directed toward the principles of transducer design [130]. Two books [131, 132] deal specifically with ship acoustics; noise degrades the performance of a ship's sonar system but also can be used to detect and track the movement of ships or aircraft.

**Music.** Noise is sound, but sound is not always noise. It has been said that one person's noise is another person's music! The facts and theory of music comprise an area of acoustics. Two of the texts listed in Table 2 are worth noting. The Traylor text [138], written for the layman, presents the basic principles of audio and physics. Instrumentation systems and their fidelity components are covered as is storage and retrieval of information on tape, film, and disc. For those interested in music and musical instruments, the book by Backus [139] is appropriate. Nisbett [137] has written for the beginner seeking information on the techniques used in broadcasting sound pickup applications.

**Materials.** In typical industrial applications the noise control engineer is involved in controlling the path of sound from source to receiver. Noise path treatment is often the only practical means of control available and is generally achieved by using absorptive materials and sound barrier materials. The number of books available in this area is small [140-142, see Table 2]. An excellent compendium, however, is available [140]. It contains information on commercial noise-reduction materials and systems and the availability of noise control products, their characteristics, and sources. This book also contains discussions on the uses and limitations of the products listed. The Acoustical and Insulating Materials Association annually publishes performance data on various acoustic materials [142].

**Handbooks/guides.** After passage of the Occupational Safety and Health Act of 1970 and the adoption of noise exposure standards, industry in general was confronted with reducing noise in the workplace. Implementation of noise control techniques prompted plant engineers to use existing results of research studies, case histories, and basic technical information to achieve maximum possible noise reductions within certain cost constraints. Handbooks that have been written to accomplish these tasks are listed in Table 2.

The Beranek text [144] and its predecessor [145] are major references used by many noise control engineers. The approach is often mathematical. The book [144] also contains many worked-out problems, discussions of theory and basics, methods of measurement, subjective reactions to noise, and data. Another old but fundamental reference handbook for the noise control engineer is the Harris text [151]. The engineering section of yet another book [165] contains control techniques that can be generally applied. Several books by Miller present noise control solutions for such industries as wood products, chemical, petroleum, and construction [172, 173, 177].

Books concerned with the control of industrial noise include that by Petrusiewicz and Longmore [154], which contains technical information on acoustics and noise control. Mathematics is minimized in explanations of principles and control procedures in the Bell text [164]. Other manuals were written as a result of government sponsorship [152, 160]. Valuable data on glass and lead materials can be found in the book by Cheremisinoff [148]. Diehl [159] has included information on practical techniques, especially for enclosure design. Yerges [158] has provided tables, charts, and graphs of materials, machinery noise characteristics, and designs for noise control. He has used very little mathematics. Useful data on estimating costs, location of noise sources, and management checklists for noise control are available [155].

Two additional texts might be of interest to practicing engineers [150, 170]. The book by Faulkner [150] treats a broad range of common industrial noise problems. The material is presented so that it can be understood by the engineer with no previous training in noise control. Step-by-step procedures for using design equations, charts, and figures are elaborated by worked examples. Standards that relate to industrial noise control are listed. Subjects include absorption, transmission loss, damping, machine element noise (gears, cams, bearings), blowers, combustion, and fluid piping. The techniques needed to solve noise problems are well developed in the other book [170], which stresses applications of theory rather than the theory itself. The text contains many example problems, illustrations, and case histories. The book should be useful to those responsible for noise control but lacking formal training in acoustics.

**Dictionaries and bibliographies.** A dictionary has been published [178] that contains more than 3500 definitions relating to acoustics. Illustrations, diagrams, graphs, and formulas are given. Each definition links concepts of many different fields: physics, music, and physicoacoustics. Such colloquial terms as bang, squeak, and clang are also defined.

Several bibliographies are presently available to the acoustics engineer and researcher. One deals with surface transportation noise reports, books, and proceedings published from 1964 to 1978 [180]. Another lists noise control legislation that exists in U.S. communities [181]. The bibliographies are not complete but do provide a starting point for research.

## PERIODICALS AND JOURNALS

The serious noise control engineer and researcher must be acquainted not only with the fundamentals but also with ongoing work. Technical seminars, committee meetings, and periodical literature provide the acoustician with the most recent methods, practices, and techniques. Periodicals and journals are essential (see Table 3). Journals concentrate on theoretical aspects; publications [195] emphasize engineering solutions to noise problems.

Table 3. Periodical Literature	
Periodicals/Journals	References
	183 thru 202

## ACKNOWLEDGEMENT

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# **LITERATURE REVIEW:** **survey and analysis of the Shock and Vibration literature**

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains articles about substructure analysis of vibrating systems and empirical modal analysis.

Dr. Robert Greif, Professor and Chairman, Department of Mechanical Engineering, and Dr. Liren Wu, Visiting Research Associate, Department of Mechanical Engineering, Tufts University, Medford, Massachusetts, have written an article summarizing work of the last three years on substructure analysis of vibrating systems. Among the topics are component mode synthesis including truncation procedures, transfer matrix methods, and condensation techniques.

Mr. Matt Rizai and Dr. James Bernard of Michigan State University, East Lansing, Michigan and Dr. John Starkey of Purdue University, Lafayette, Indiana have written a paper presenting a short history of modal testing and a review of developments over the last seven years, including multiple-point excitation and design modification based on modal test results.

## SUBSTRUCTURE ANALYSIS OF VIBRATING SYSTEMS

R. Greif\* and L. Wu\*\*

**Abstract.** *This article summarizes work of the last three years on substructure analysis of vibrating systems. Among the topics are component mode synthesis including truncation procedures, transfer matrix methods, and condensation techniques. The discussion includes applications to a variety of engineering problems as well as nonlinear and non-conservative systems.*

Substructuring and synthesis techniques are used to solve problems of vibrating systems in which large number of degrees of freedom are involved. Component mode synthesis (CMS) in particular has been effective; research is continuing on methods for improving the accuracy and efficiency of operation, modal truncation, and techniques for inclusion of CMS in general purpose finite element programs. Synthesis concepts are included in such modern vibration texts as Thomson [1] and Craig [2]; engineering students are thus introduced to the concepts. A review of this subject has been given by Nelson [3]. Pioneers of component mode synthesis include Kron [4], whose work involved circuit theory but is applicable to mechanics problems analyzed today. Kron incorporated subsystems and free interface modes into his work. Simpson and Tabarrok [5] discussed and clarified Kron's work for mechanical and structural engineers.

### GENERAL THEORETICAL CONCEPTS

Current research into component mode and synthesis techniques is aimed at increasing accuracy and optimizing computer time. Component modes studied include free interface normal modes, fixed interface normal modes, rigid body modes, constraint modes, attachment modes, inertia relief modes and branch modes [6].

Clark [7] studied component modes obtained from deflections due to static loads of two types: attachment modes and fixed interface modes. Nagamatsu and Ookuma [8] considered a method in which substructuring involved a combination of different component modes. The synthesis was performed by using branch modes for certain substructures in combination with fixed interface and constraint modes for other substructures. Zhu [9], who extended the ideas of Rubin, used a subspace base vector matrix consisting of a modified lower frequency mode matrix (including rigid body modes) to define dynamic displacements; he used a modified residual flexibility matrix of higher frequency modes to define static displacements.

The Lagrange multiplier approach has been used to synthesize component modes from various substructures. Dowell investigated structural systems based upon free unconstrained components; Greif [10, 11] utilized Fourier sine or cosine series for the modal displacements in the components. The Lagrange multipliers were used as independent variables and became part of the eigenvector in the frequency analysis.

Kerstens [12, 13] used the modal constraint method to investigate coupled systems with Lagrange multipliers. The Lagrange multipliers were used in a different manner than previously in that they were expanded in terms of generalized coordinates.

Dowell [14] did an elegant analysis of the effect of combining dynamical systems based upon a Lagrangian formulation with constraints included via Lagrange multipliers. He showed that, if two component systems are connected at a point, each combined system frequency is increased from its component value or, in the exceptional case, is unchanged.

Stavriniadis [15] used the Lagrange multiplier method to couple dynamical systems; the technique is appar-

\*Professor and Chairman, Department of Mechanical Engineering, Tufts University, Medford, MA 02155

\*\*Visiting Research Associate, Department of Mechanical Engineering, Tufts University, Medford, MA 02155; also Lecturer, Harbin Shipbuilding Institute, Harbin, People's Republic of China

ently incorporated in the ASKA program. He used independent master degrees of freedom in conjunction with static condensation to reduce the order of the combined system.

Significantly less research has been done on substructuring and synthesis for problems that have either heavy damping or nonproportional damping or that lead to complex eigenvalues and eigenvectors. Typical systems that produce such nonclassical vibration problems are structures with concentrated dampers, soil/structure systems, structures with rotating parts, and railroad vehicles that include modeling of the wheel-rail interaction effect due to creep force.

Glasgow and Nelson [16] improved Hasselman's complex mode transformation by using static constraint modes instead of an identity matrix in the transformation relations between generalized coordinates. Craig and Chung [17] applied free interface complex modes to beam vibration problems. They did not discuss the supplement to the transformation needed when a rigid body mode occurs in a subsystem.

Wu and Greif [18] presented a new approach to the damped system analysis that easily includes the effects of the rigid body modes of the substructures. The technique uses two successive transformations to the equations, making use of free interface modes followed by fixed interface modes.

Although Traill-Nash [19] did not explicitly consider substructuring, he studied the nonclassically damped problem on the basis of the mode displacement and force summation methods, with damped modes and undamped modes. He suggested that the method of force summation with damped modes is the most effective procedure when damping is nonclassical.

One use of substructuring is to produce a dynamic analysis that leads to a reduction in computer time and generally increases the efficiency of solution. A typical procedure in modal synthesis is the partial mode or modal truncation technique.

Li and Gunter [20] investigated modal truncation in each subsystem of a two-spool gas turbine engine. They used two modal truncation criteria: the first

is based on an upper frequency limit of the subsystem; the second is based upon the strain energy of the subsystem as proposed by Tolani and Rocke [21]. For the engine problem studied they recommended the selection of component modes based upon the upper frequency limit.

Another recent study of the error due to truncation was done by Natke [22]. Condensation or eigenvalue economization also can greatly reduce computational effort. Rohle [23] classified the condensation technique; Pekau and Huttelmaier [24] investigated multilevel Guyan condensation and used the word superelement. They focused on solution accuracy for different representations of mass and recommended a consistent substructure mass matrix.

Leung [25] further developed an accurate dynamic condensation technique for use with substructures. The method uses physical coordinates (rather than modal coordinates) to satisfy the condition of compatibility. Substructures are identified by a few lowest fixed-interface modes in conjunction with static constraint modes. The dimension of the fundamental matrices is equal to the number of interface coordinates (masters) for each substructure.

In contrast to Leung, Arora and Nguen [26] reduced the scale of the eigen-problem not by condensation but by using the technique of mathematical efficiency according to the fact that only a few modes are required. They developed compatibility conditions in terms of interface coordinates in an exact form similar to dynamic condensation and used subspace iteration to solve the whole system. An open truss helicopter tail-boom structure was used to demonstrate the method.

Hale and Meirovitch [27-29] did an extensive study of ordinary admissible function representation for substructures. The advantages of admissible functions over substructure modes are an increase in the number of functions and low order polynomial representation that simplifies computation. The geometric compatibility conditions are approximately enforced by the method of weighted residuals. Convergence of the eigenproblem is analyzed by increasing the number of substructure admissible functions and the number of internal boundary weighting functions. The admissible function method has also been used by Hodges [30] to analyze the eigenproblem for

Sturm-Liouville systems with discontinuous coefficients, as exemplified by a nonuniform rod.

The transfer matrix method [31-35] is a substructuring technique that is being researched less intensively than the CMS and related methods. The advantage of the transfer matrix method is automatic reduction in matrix size without the need to truncate degrees of freedom. However, the method is most efficient when applied to structures with chain-like topology. An improvement in the accuracy of the transfer matrix method has been to introduce the branching concept in a long system [36]. In a long system a short section is treated as a branch and then absorbed into the next longer section. The successive absorption of the previous branches is the new contribution. Accuracy can be checked by examining the stiffness of the dynamic stiffness matrices.

The finite strip method can be considered equivalent to a substructuring technique although it is usually applied to specific structures such as plates and shells. Dawe and Morris [37] solved the problem of vibration of curved plate assemblies including the presence of an initial membrane stress field. The presence of the membrane stress field was accommodated in the analysis by the inclusion of an initial stress or geometric stiffness matrix.

Substructuring is also used for vibrating systems in which statistical energy analysis and power flow concepts are used in the solution. Smith [38] used statistical energy analysis to analyze the random response of two identical subsystems coupled at an end with a general coupling. The results showed the importance of cross-correlation between the wave fields incident on the coupling and also the importance of the asymmetry of the wave field. Similar concepts were used by Goyder and White [39-41] for the vibration analysis of beam and plate-like foundations and for a related vibration isolation problem. Useful tables are given for driving point mobility and input power flow due to torque or force excitation.

Substructuring also can be used for combined analytical-experimental techniques of solution. Cromer [42] used a building block approach in which components with properties determined experimentally were connected to components modeled by finite

element techniques. Results are given for a beam bending problem and a practical industrial example involving a model of a gas diffusion column; comparison between experimental and theoretical results is very good. Goyder [43] investigated mathematical models of structures based upon experimentally determined frequency response. He showed that, by modeling two separate components from measured data, it is possible to estimate the subsequent motion and power flow through the two components when coupled.

## NONLINEAR, NONCONSERVATIVE SYSTEMS

Dynamic analyses of nonlinear and nonconservative systems are a logical development of the expanding use of component mode synthesis and substructuring methods. Dowell [44, 45] applied the modes of continuous components with the Lagrange multiplier method for connection components and the method of harmonic balance to study this problem. Among the problems studied by Dowell are a nonlinear conservative system (beam/nonlinear spring), a linear nonconservative system (plate/fluid flow), and a nonlinear nonconservative system (beam/nonlinear damping). Numerical examples are given for a single nonlinear nonconservative element; there is no difficulty in generalizing Dowell's method for multiple nonlinear elements. However, for systems with a continuous system of nonlinear dissipation (nonlinear damping in a beam) the solution of the resulting nonlinear algebraic equations can be difficult.

Bathe and Gracewski [46] studied systems with geometric and material nonlinearities. The nonlinear dynamic equilibrium equations were solved using mode superposition, substructuring, and synthesis; the solutions were compared to complete direct integration solutions. An implicit time integration method and a modified Newton iteration were used to establish dynamic equilibrium at discrete times. Condensation was shown to be effective for large problems with small isolated areas of nonlinearities. In these problems the linear degrees of freedom are statically condensed prior to solution of the incremental equations of equilibrium. Component mode synthesis was also used effectively. Specific guidelines were drawn for efficient use of substructuring and component mode synthesis.

These techniques have been implemented in the general purpose finite element program ADINA. Although Dodds and Lopez [47] investigated the static analysis of linear and nonlinear structures, the concept of multilevel substructuring is certainly valid for dynamic analysis of large complex systems. The paper examines the relative advantages of user-defined substructuring and condensation relative to data entry, computational efficiency, and machine resource utilization.

Sato [48] investigated the nonlinear free vibration of stepped thickness beams by assuming sinusoidal responses and using the transfer matrix method. He compared the results to those obtained by a Galerkin method that retains the linear mode function of the beam.

## APPLICATIONS

The substructuring and component mode synthesis methods discussed in this review are general and can be applied to solutions of many practical problems. In some fields surveys are available. For spatially periodic structures the transfer matrix technique is efficient; additional advantage is obtained when characterization of the periodicity is taken into account [49-54]. A survey of this method is available [55]. Physical systems investigated vary from multi-span plates to rotating bladed discs and the dynamics of rotationally periodic large space structures.

Another field of practical interest that involves extensive use of substructuring is soil-structure interaction. Vast differences are typically found between the damping properties of the structures and the supporting soil/ground system [56-58]. A review article has been presented [59].

El-Shafee [58] included a study of the dynamic behavior of a hyperboloidal cooling tower shell on discrete supports with a ring footing. Johnson [59] used the substructure approach to treat the problem in a series of steps -- determination of foundation input motion, determination of foundation impedances, and analysis of coupled systems.

The substructuring technique has been helpful in the dynamic analyses of acoustic systems, acoustic-

structural systems, and fluid-structural systems. Ross [60] applied the concept of CMS to parallel-coupled acoustic systems with the conventional acoustic four-pole network. In a structural-acoustic analysis of an automobile passenger compartment [61] CMS was applied as a straightforward analogy to the CMS method in structural dynamics. Both the acoustic field and the structure were modeled by the finite element method and coupled by displacement and pressure. This paper also contains a comprehensive listing of the literature in the field.

Daniel [62] extended Hurty's method to the fluid-structure eigenvalue problem. He investigated several combinations of modes corresponding to different sets of generalized coordinates for a symmetric form of the matrix differential equation of the fluid field and included both compressible and incompressible fluids. Stussi and Jemelka [63] studied the transient response of fluid-coupled coaxial cylindrical shells by using Bessel functions for the pressure field of the water; mode functions corresponding to cantilevered beams were used with the Fourier transform in the frequency domain. A flooded containment of a nuclear power plant under earthquake load was analyzed.

A number of papers have to do with the dynamics of rotating systems. Li [64] compared solutions for the vibrations of complex multilevel flexible rotor systems by CMS with solution by the transfer matrix method. Criteria for the selection of truncated modes in CMS were evaluated. The transfer matrix method was combined with CMS in an analysis of a shaft-impeller system [65]; agreement with experimental data was satisfactory.

Aboul-Ella and Novak [66] investigated the dynamic response of turbomachinery frame foundations; they considered the interaction of soil, piles, mat, frame, oil/film in the bearings, and assembly of shafts and disks. The methods for reduction of degrees of freedom applied included the impedance method, condensation, and the component mode method. Glasgow and Nelson [16] and Nelson and Meacham [67] applied complex mode synthesis to rotor/bearing systems for stability and transient analyses.

Yargicoglu [68] employed substructuring in a three-dimension finite element model to predict the influence of structural discontinuities on composite rotor

blades. Schmidt [69] employed CMS, specified as free-interface modes, to analyze a bladed disk and compared results with experimental results. Li and Gunter [70] investigated large multicomponent flexible rotor systems using CMS. The flexible connections between elements were introduced as generalized damping, stiffness, and forces into the modal equations. The technique was applied to a two-spool aircraft gas turbine engine equipped with a squeeze-film damper bearing and to the space shuttle main engine oxygen turbopump; in the latter both the dynamics of the rotor and the housing were considered.

CMS is a powerful technique for studying the dynamics of spatial mechanisms. Sunanda and Dubowsky [71, 72] used it to study complex linkage systems that are capable of three-dimensional motion. The technique is also applicable to the dynamic behavior of robotic manipulators.

Kukreti and Feng [73] used the branch method of Gladwell and Benfield to formulate an efficient design analysis for systems. The method has been used to investigate design changes in a system due to alterations in geometry or configuration of a subsystem. An example is given for the dynamic response of a multistory rigid frame subject to lateral ground acceleration.

In 1980 Sandstrom [74] applied CMS in a study of ship vibration. Introduction of a condensed version of the component mode equations led to matrices of lower order, thereby greatly reducing computer storage requirements and computational effort. Berman [75] used a generalized coupling technique to combine independently modeled components in analyses of helicopters.

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## EMPIRICAL MODAL ANALYSIS

M.N. Rizai,\* J.E. Bernard,\* and J.M. Starkey\*\*

*Abstract. Test apparatus that digitize analog signals and use fast Fourier transforms and related analytical tools to determine natural frequencies and mode shapes are now routinely available to test engineers. The equipment and associated test techniques, called modal testing, are now an important aspect of structural analysis in the initial design process, in design verification, and in troubleshooting. This paper presents a short history of modal testing and a review of developments over the last seven years, including multiple-point excitation and design modification based on modal test results. The paper concludes with a brief review of the closely related topic of acoustic intensity.*

The literature concerning modal testing dates from the 1940s, when work for determining modal characteristics from test data was presented by Kennedy and Pancu [1]. Their testing was done with analog devices. In the mid 1960s, with the advent of the Cooley-Tukey fast Fourier transform (FFT) algorithm [2] and continued improvement of digital computers, modal testing using digital hardware became more practical. This period was well summarized in 1971 by Klosterman [3], who presented a theoretical foundation for experimental modal analysis and reviewed the literature to that date.

Digital methods for modal testing developed rapidly during the early 1970s. In 1975 Richardson [4] reviewed methods for identifying modal characteristics from frequency response function measurements and discussed alternative methods. He also presented various techniques for frequency response function measurements using a Fourier analyzer. Ramsey [5, 6] discussed several excitation techniques for measuring frequency response functions with a Fourier analyzer and digital techniques for identifying closely coupled modes via increased frequency resolution. Several good references were published between 1971 and 1975 [7-9].

\*Department of Mechanical Engineering, Michigan State University, East Lansing, MI 48824

\*\*Department of Mechanical Engineering, Purdue University, Lafayette, IN

This paper concentrates on developments since 1975, including several methods to improve testing procedures and the use of modal test equipment in acoustics.

### MULTI-INPUT EXCITATION METHODS

The majority of modal testing is done with either multi-shaker sine excitation or single input excitation [6, 10]. In theory single input excitation provides the information necessary to extract the modal characteristics of a structure. In practice, however, the necessary information depends on exciter location, size of the structure, and damping. Multi-input excitation improves the results of modal testing because more accurate frequency response functions are obtained.

Three multi-input excitation methods have been proposed. Richardson and Kniskern [11] have suggested that a good estimate of the modal vector can be obtained by exciting the structure with more than one input excitation and calculating a column or row in the residue matrix for each excitation point. The redundant information can be scaled and averaged to improve the accuracy of the modal vectors. The cost of the increased accuracy is the increased time required to generate the added residue columns.

Allemang, Rost, and Brown [12] have also proposed a multi-input excitation technique. They investigated the potential of the multiple input estimation approach to formulation of the frequency response function by formulating the multiple coherence function. They verified their study with dual input testing. Their goal was to improve all modal parameters and reduce time required per measurement and in subsequent analyses.

A third method for estimating modal parameters has been developed by Vold, Kundrat, Rocklin, and Russell [13]. The method utilizes free vibration time histories of response points under impulse loadings at the exciter locations.

### PARAMETER ESTIMATION METHODS

The modal parameters -- natural frequency, damping, and mode shapes -- of a structure can be obtained from measured frequency response data. The methods can be separated into two categories: single-degree-of-freedom curve fitting (SDOFCF) and multi-degree-of-freedom curve fitting (MDOFCF).

SDOFCF methods extract parameters one mode of vibration at a time. These methods use information of such equivalent forms as real and imaginary part or magnitude and phase of the frequency response function. SDOFCF methods give accurate estimates if the structure is lightly damped and natural frequencies are well separated. The more popular SDOFCF methods in use at present include circle fitting, which uses real and imaginary complex plane information [14], and second order polynomial fitting on frequency response functions [15].

MDOFCF methods assume more than one degree of freedom in a given frequency range of interest and extract several modes of vibration from a given frequency response function. These algorithms can be implemented in the time domain or the frequency domain. The common least squares complex exponential technique uses unit impulse response functions. This method and several others have been discussed [16].

### THE VALIDITY OF THE MEASURED DATA

A complete modal vector for a particular natural frequency can be obtained by measuring one row or column of a frequency response matrix. Although this process requires minimum time to obtain the modal vectors, it is not always possible to significantly excite all modes of a structure from a single excitation point. As a result these modal vectors can be inaccurate. Allemang [17] presented a technique to determine the consistency of the modal vectors obtained from multiple columns or rows of a

frequency response matrix. He provided a scalar modal assurance criterion as a measure of consistency.

After all modal data have been obtained, frequency response functions can be analytically recreated from modal data. The validity of modal data can thus be assessed by synthesizing various frequency response functions from the modal parameters and comparing them with measured data. This process, called modal synthesis, is useful for checking the validity of the modal parameters and has been incorporated in current modal testing software [14, 15].

### PREDICTION AND SPECIFICATION TECHNIQUES

As modal testing techniques have become more refined, the accuracy of the resulting modal data has improved. More accurate natural frequencies, modal vectors, and damping coefficients have made possible the construction of reliable mathematical models for structures from modal test data. These models are now being used to predict the effects of proposed design changes on structural dynamics (prediction) and to determine modifications needed to produce desired structural dynamics (specification). Some of these techniques have been reviewed [18, 19].

Meirovitch [20] has used the Rayleigh quotient to predict the effects of a known design change on system natural frequencies. Formulations for the derivatives of natural frequencies with respect to given changes have been given [21, 22]. These derivatives can be used in a Taylor series to predict new frequencies. Both techniques assume that the modal vectors remain unchanged; this assumption is usually accurate for small changes.

Assumed modes methods, however, allow new modal vectors to be any linear combination of the original modal vectors. White and Maytum [23] have presented this method for discrete systems. Weissenburger [24] found a simple form for the characteristic equation of a modified system for rank-one modifications; that is, changes in a single spring or mass element. Formenti [25] used Weissenburger's technique in a beam example and showed that modal test data can be used in the formulation. Pomazal and Snyder [26] extended Weissenburger's work

to include general viscous damping in both the original system and the modifications. Hallquist and Snyder [27] used Weissenburger's technique to couple subsystems.

Hirai and Yoshimura [28] and Wang and Chu [29] have presented receptance methods for predicting undamped symmetric systems with symmetric mass and stiffness modifications. They take advantage of the fact that design changes often affect a small subset of the degrees of freedom of the original system. When set to zero the resulting small order determinant yields the characteristic equation of the new system.

Wang, Palazzolo, and Pilkey [18] extended the receptance techniques to include proportional viscous damping in the original system with general damping in the modifications. Related references are Kron [30], Simpson [34], and Youssefi [32].

Wilkinson [33, 34] and Parlett [35] indicate that solving for the roots of the characteristic equation is not always a reliable way to find the eigenvalues of a system. The reason is that the roots of a polynomial can be strongly affected by measurement error or by small errors introduced into the polynomial coefficients by previous computations. Caution must thus be exercised with techniques in which natural frequencies are obtained from the characteristic equation, especially for large order systems.

Prediction techniques are analytical tools used to predict the dynamic characteristics of a modified system. But a designer would like to specify improved dynamic characteristics and compute the needed design changes; several authors have addressed this problem.

Stetson and Palma [36] have used rank-one matrices, each with an unknown coefficient, in Rayleigh's quotient to generate sets of linear equations. Similar ideas have been used to adjust existing analytical models to match modal test results [37, 38].

White and Maytum [23] have specified natural frequency and defined its associated modal vector in terms of  $m$  original modal vectors. They used an assumed modes approach to generate a set of  $m$  linear equations in  $m$  unknown amounts of given changes. This method has been used to adjust a modal analytical model to match modal test data [39].

Weissenburger's technique [24], which can be classified as an assumed modes method, can be used to specify one natural frequency and solve for the amount of one needed design change. However, additional changes made with this technique can move frequencies specified earlier.

Wang, Palazzolo, and Pilkey [18] used receptance methods with rank-one modification matrices to specify desired natural frequencies. They included static deflection of the structure to help account for higher modes excluded from the modal analysis data.

In contrast with techniques that attempt to force given natural frequencies to take on certain values, several authors have investigated frequency-constrained structural optimization as a less restrictive way to improve dynamic characteristics. These techniques attempt to minimize a cost function, such as weight, subject to inequality constraints on one or more natural frequencies [40-46]. This literature has been reviewed [47-50]. A good text on design optimization with frequency constraints is that of Haug and Arora [51].

## ACOUSTIC INTENSITY

In the past acoustical experiments relied on the measurement of sound pressure, which is a scalar quantity. Because these measurements are a summation of all the sound impinging on a measurement device, measurements are affected by the test environment, and special acoustical test facilities were often needed.

The measurement of a vector quantity known as acoustic intensity has been developed by Chung [52]. The cross spectral density of the sound pressure is measured at two closely spaced microphones held perpendicular to the noise radiating surface. The cross spectral density can readily be measured using modern two-channel modal test equipment. Because the method yields a measure of the sound from a particular direction, testing can be done with less concern about contamination of data from other sound sources; the measurement thus can often take place in more convenient locations than were previously advisable.

Chung and Blaser [53] discussed factors that affect the measurement accuracy of the cross spectral

method. They include microphone type, microphone spacing, correction for phase mismatch, and signal to noise ratio. Crocker [54] reviewed the application of modern digital signal processing techniques to acoustic intensity measurements. Experimental verification of the method has been presented [55, 56].

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# BOOK REVIEWS

## TRIBOLOGY -- FRICTION, LUBRICATION AND WEAR

A.Z. Szeri, editor

McGraw-Hill Book Co., New York, NY  
1980, Book No. ISBN 0-07-062663-4

**Tribology -- Friction, Lubrication and Wear** is an excellent text on tribology for undergraduate students and a good reference source for practicing engineers. The 11 chapters were written by experts in the field of tribology; the book was edited by A.J. Szeri.

The first two chapters are an introduction to tribology. The first chapter, written by the editor, includes a brief history of tribology, basic laws of friction, lubrication regimes, and type and selection of bearings. R.A. Burton introduces early and modern concepts of surface contact in a chapter on friction and wear. The mechanisms and laws of friction are discussed and illustrated with appropriate experimental evidence. The subject of wear, however, is only briefly mentioned.

In chapter three, written by the editor, the Reynolds equation is derived from first principles. The equation is applied to hydrostatic and hydrodynamic bearings and elastohydrodynamically lubricated contacts. In chapter four C.T.H. Pan discusses gas bearings in detail. The relevant theory for most types of bearing geometries is included. This chapter contains considerable design data and is a good design manual on self-acting and externally-pressurized gas bearings.

Chapter five by the editor contains discussions of turbulence, inertia, and thermal effects in fluid-film bearings. These effects are generally neglected in conventional bearing design. Their importance in the design of large bearings has recently been realized, however, and this chapter provides up-to-date design information.

Chapter six by S.M. Rohde describes various computational techniques for solving one- and two-dimen-

sional fluid-film lubrication problems. Solutions for dynamically loaded bearings and elastohydrodynamic lubrication contacts are also given.

Chapter seven on rotor/bearing dynamics, written by C.H.T. Pan, begins with elementary concepts (motion of a constrained mass point) and goes on to dynamic coupling mechanisms. An analysis of symmetrical and unsymmetrical rigid rotors supported between fluid-film bearings is presented.

In chapter eight on rolling element bearings W.J. Anderson describes bearing types and methods of lubrication from a practical viewpoint. Analytical descriptions of friction, contact stress, contact deformation, and load distribution are also presented.

In chapter nine L.B. Sargent describes liquids (mineral and synthetic), solids, semisolids, and gases used as lubricants. Such topics as health, safety, and toxicity that relate to the use of lubricants are also included.

The final two chapters, written by H.N. Kaufman, have to do with bearing materials and damage analysis. Chapter 10 provides characteristics of various metallic and nonmetallic materials for fluid-film and rolling element bearings. The final chapter deals with failure of bearings as a result of fatigue, corrosion, wear, wiping, and erosion. This chapter should be particularly useful to practicing engineers who must diagnose bearing failures.

Both imperial and S.I. units are used. The material is presented in a clear and easily readable style; the text is appropriately illustrated by excellent diagrams and photographs.

D. Koshal, Senior Lecturer  
Department of Mechanical  
and Production Engineering  
Brighton Polytechnic  
Brighton, East Sussex. BN2 4GJ, England

## AN INTRODUCTION TO THE PRINCIPLES OF VIBRATIONS OF LINEAR SYSTEMS

P. Thureau and D. Lecler; Transl. by J. Grosjean  
John Wiley and Sons, New York, NY  
1981, 131 pp, \$17.50, Book No. 0-27230-9

The book is a mathematical treatment of the theory of vibration of linear oscillators and is intended for applied science students. Physical explanations that relate the analytical presentations to mechanical engineering problems in vibrations are kept to a minimum; hence the book is limited in terms of adaptability or as a reference for engineering students. Electrical analogies are given, but example problems are very few.

The book covers single- and two-degree-of-freedom systems and contains a brief treatment of continuous systems. There is no coverage of multi-degree-of-freedom systems, which is standard in any book on vibrations. The book does not mention the matrix analysis approach, which is essential in the treatment of vibration problems. The text also contains many printing errors.

T.S. Sankar  
Professor and Chairman  
Department of Mechanical Engineering  
Concordia University  
1455 de Maisonneuve Blvd. W.  
Montreal, Quebec H3G 1M8 Canada

## TRANSIENT WAVES IN VISCO-ELASTIC MEDIA

N.H. Ricker  
Elsevier-North Holland Pub. Co., New York, NY  
1977, 278 pages

Transient wave propagation in a viscoelastic medium is treated in this book. One-dimensional problems (one spatial dimension) are discussed; the entire book has to do with what the author calls Stokes' wave equation. The viscoelastic model considered here is actually what is commonly known as a Kelvin solid. The author leaves the reader with the impression that only this model need be considered to understand the dissipation properties of earth materials. This is a gross simplification. It is surprising that the author relegates all recent studies on attenuation in the earth to a two-page discussion in Chapter 17. The remainder of the book is devoted to a detailed algebraic and numerical treatment of the author's wavelet expansion procedures for studying transient solutions of Stokes' wave equation. Although such treatment might be useful in studying certain special problems, it is of little value in understanding transient wave propagation in viscoelastic media. The interested reader will have to look elsewhere for a more complete treatment of this problem.

S.K. Datta  
Professor of Mechanical Engineering  
University of Colorado  
Boulder, Colorado 80306

# SHORT COURSES

## FEBRUARY

### **VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION**

Dates: February 7-11, 1983  
Place: Santa Barbara, California  
Dates: March 7-11, 1983  
Place: Washington, DC

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 682-7171.

### **PERIPHERAL ARRAY PROCESSORS FOR SIGNAL PROCESSING AND SIMULATION**

Dates: February 15-18, 1983  
Place: Los Angeles, California

Objective: The primary emphasis of this course is on the application of peripheral array processors to the principal problems arising in the processing of sampled analog signals. These include particularly the problems of spectral analysis (Fast Fourier Transform), filtering, and autocorrelation, which are typical of signal processing applications.

Contact: Short Course Program Office, UCLA Extension, P.O. Box 24901, Los Angeles, CA 90024 - (213) 825-1295 or 825-3344.

### **MACHINERY VIBRATION ANALYSIS**

Dates: February 22-25, 1983  
Place: Tampa, Florida  
Dates: June 14-17, 1983  
Place: Nashville, Tennessee

Dates: August 16-19, 1983  
Place: New Orleans, Louisiana  
Dates: November 15-18, 1983  
Place: Chicago, Illinois

Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

### **DYNAMIC BALANCING SEMINAR/WORKSHOP**

Dates: February 23-24, 1983  
March 16-17, 1983  
April 27-28, 1983

Place: Columbus, Ohio

Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single-, two-, and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels,

etc. with emphasis on reducing costs and improving quality in balancing operations.

Contact: R.E. Ellis, IRD Mechanalysis, Inc., 6150 Huntley Road, Columbus, OH 43229 - (614) 885-5376.

#### **SYSTEMATIC APPROACH TO IMPROVING MACHINERY RELIABILITY IN PROCESS PLANTS**

Dates: February 23-25, 1983

Place: San Francisco, California

Objective: This seminar is intended to guide machinery engineers, plant designers, maintenance administrators, and operating management toward results-oriented specifications, selection, design review, installation, commissioning, and post start-up management of major machinery systems for continued reliable operations. Emphasis will be on pumps, compressors, and drivers.

Contact: Sherry Theriot, Professional Seminars International, P.O. Box 156, Orange, TX 77630 - (713) 746-3506.

### **MARCH**

#### **EXPLOSION HAZARDS EVALUATION**

Dates: March 14-18, 1983

Place: San Antonio, Texas

Objective: Fundamentals of combustion and transition to explosion including recent experimentation on large-scale systems, current testing techniques and their utility, accidental explosions, and preventive measures are reviewed. Free-field explosions and their characteristics including definition of an explosion, characteristics of explosions, and the fallacy of "TNT" equivalence are defined. Loading from blast waves such as reflected waves -- both normal and oblique, diffraction and diffracted loads, internal blast loading, and effects of venting will be covered. Structural response to blast and non-penetrating impact including approximate methods, the P-i concept, Bigg's methods, numerical methods, and applicable computer codes will be reviewed. Fragmentation and missile effects (trajectories and impact conditions), thermal effects (fireballs from explosions and radiation propagation), damage criteria (buildings, vehicles, and people), and design for blast and impact resistance (general guidelines, design using approximate methods, and computer-aided design) will be reviewed.

Contact: Ms. Deborah Stowitts, Southwest Research Institute, P.O. Drawer 28510, 6220 Culebra Road, San Antonio, TX 78284 - (512) 684-5111.

# **NEWS BRIEFS:** news on current and Future Shock and Vibration activities and events

## **Call for Papers**

### **SECOND INTERNATIONAL MODAL ANALYSIS CONFERENCE**

The 2nd International Modal Analysis Conference, sponsored by Union College, Schenectady, New York, will be held November 7-9, 1983 (location to be announced).

The purpose of the Conference is to provide a forum for all those concerned with the rapidly changing technology of modal analysis. Papers are sought on the following topics:

Mechanical Impedance	Modal Testing Software
Processing Modal Data	Experimental Techniques
Finite Element Analysis	Computer Graphics
Substructuring	Structural Dynamics Modification
Case Histories	Transducers and Instrumentation
Linking Analysis and Test	Modeling
Analytical Modal Analysis	Design Methods

Authors should submit a short abstract of the paper (not more than 200 words) by March 1, 1983 to: Peter B. Juhl, Union College, Graduate and Continuing Studies, Wells House - 1 Union Avenue, Schenectady, NY 12308-2363 - (518) 385-9721. If the abstract is selected, the author will be asked to submit his finished paper, suitable for publication, by July 1, 1983.

# REVIEWS OF MEETINGS

## **53RD SHOCK AND VIBRATION SYMPOSIUM**

**26 to 28 October, 1982**

**Radisson Ferncroft Hotel**

**Danvers, Massachusetts**

The 53rd Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in Danvers (near Boston) in October. It was hosted by the U.S. Army Materials and Mechanics Research Center. The formal technical program consisted of more than 60 papers (see Vol. 14, No. 9 of the DIGEST for the complete program; paper summaries are available from the SVIC; papers will be published in the SHOCK AND VIBRATION BULLETIN). Technical plenary sessions were conducted during the Symposium. Dr. Eric E. Ungar delivered the fourth Elias Klein Memorial Lecture -- "Vibration Challenges in Microelectronics Manufacturing." In the second plenary session Mr. Gene M. Remmers gave the Maurice Biot 50th Anniversary Lecture -- "The Evolution of Spectral Techniques in Navy Shock Design." The third plenary address on "Materials Implications of Advanced Thermal and Kinetic Energy Threats" was given by Mr. Robert Fitzpatrick and Mr. John F. Mescall -- both of the U.S. Army Materials and Mechanics Research Center. A large and interesting session on short discussion topics covering many areas of mechanical vibration and shock was again held. Finally an interesting panel session on MIL-STD-810D was moderated by Mr. Preston Scott Hall of the Air Force Wright Aeronautical Laboratories. Henry Pusey, Director of SVIC, the members of the SVIC staff, and the program committee are to be congratulated for the assembly of an outstanding program on shock and vibration technology. Among the 350 participants were representatives of the federal government, industry, academic institutions, and foreign nationals from NATO countries. The combination of formal and informal technical programs effected a meaningful transfer of shock and vibration technology.

## *The Opening Session*

Richard Shea, chairman of the opening session, introduced Dr. Edward S. Wright, Director of the U.S. Army Materials and Mechanics Research Center (AMMRC), who gave the welcome address. Dr. Wright acknowledges the history and the stature of the Symposium and of its role as a key organization for technical information interchange. He spoke about the areas of interest, location, and capabilities of AMMRC (the corporate lab of DARCOM). He cited their areas of interest -- materials processing, materials development, and manufacturing technology and their IAC responsibilities.

The keynote address was given by Major General Story C. Stevens who spoke on "AVRADCOM Research in Helicopter Vibrations." This was a very interesting talk with solid technical data on helicopter vibrations. He showed the downward trend of helicopter vibration levels over the years through design improvements in the structure. Vibration reduction devices will be used when structural design has been optimized. The Army helicopter mission requirements include high speed flight, advanced weapons, survivability, and transport. General Stevens described the vibration problems with modern Army helicopters -- UTTAS and AAH. He discussed solutions to these problems including local vibration isolation. General Stevens noted that vibrations limit flight envelopes -- human factors, reliability, structural integrity, maintainability. He discussed vibration versus reliability and maintainability, transportability requirements, and the impact of vibration on productivity. General Stevens gave an assessment of present vibration technology including vibration design considerations -- periodic loads, rotor downwash, and passive isolation versus active control devices. The role of vibration testing of helicopters was discussed. He discussed rotor vibratory loads including loads analysis, airframe structural dynamics, rotor/airframe coupling, vibration control devices,

and types of vibration tests. Current AVRADCOM vibration research including advanced vibration control, advanced vibration testing techniques, passive design, component design (main rotor isolation) was discussed in detail. General Stevens gave his impressions on future needs in vibration analysis, testing, and control. He noted that more applied technology is needed -- wind tunnel testing, finite element modeling, testing techniques, aerodynamic phenomena, and active controls were among the areas noted. He concluded his presentation by noting the payoffs to Army aviation available from vibrations research.

Five interesting talks were given by the invited speakers. Mr. Henry Pusey, Director of SVIC, gave the first talk on "Technical Information Support for Survivability Programs." Mr. Pusey discussed the need, existing resources, proposed resources, technology sources and users, the concept of a shock and vibration information and analysis center, the coordination function, and recommendations for future activities. This was a comprehensive presentation on a program for the management of technical information. The need for technical information coordination support is defined by DOD policy -- directives 5000.2 and 5000.3. It involves many complex systems and is multidisciplinary in nature. Primary and secondary information on combat data and computer models must be identified. Mr. Pusey noted that cross fertilization among users will be important. He noted the threat related technologies such as air blast, shock, and vibration; survivability design; and secondary effects. Mr. Pusey discussed the existing resources -- CDIC, DASIAC, SVIC, computerized model deposit, and other sources. He discussed proposed resources including the SURVIAC proposal for aircraft survivability and the SVIC proposal for fleet survivability. Technology sources and users were identified from unit summary reports (1498) -- Army, Navy, Air Force and other DOD sources. A large table relating threat related technologies to users was shown. He showed places where new technology will be required and the users of such technology. In many cases they were the same organization. Mr. Pusey discussed publications -- current awareness type, state-of-the-art monographs, annotated bibliographies, surveys, guidance documents, and standards; direct response to users -- searches, analysis, consulting, guidance, interpretation, referral, special teams, and access to data bases; training --

symposia, seminars, workshops, and short courses; and systems oriented groups -- methodology, threat definition, counter measures, survivability design, vulnerability assessment, standardization, and computer models. He noted that the survivability technical base will support systems oriented groups. The functions will include coordination, program management liaison, data bases, training, and user service -- with expert consultants available. In closing Mr. Pusey showed how a coordinating activity would interface technology sources and users in survivability information activities. He recommended that SURVIAC and SVIC be developed further, that structures for computer activities be developed, and that an in-depth workshop be conducted among DOD users and IAC personnel to answer all questions on survivability.

Mr. Dale B. Atkinson discussed aircraft survivability in a talk coordinated with Mr. Pusey. He stated the DOD survivability policies including DOD directive 5000.3 and the current objectives -- to ensure that naval weapons systems and mission equipment are capable. He gave the organizational responsibilities, current programs, type of R&D conducted, vulnerability tests and reduction techniques, signature testing, and development survivability evaluations. Mr. Atkinson discussed information dissemination including publications and courses in some depth.

The third invited speaker was Captain F.S. Hering who spoke on fleet survivability. He noted that increasing the survivability of a combat ship makes it larger and heavier whereas the trend is to lighter more maneuverable ships. He discussed information on threats obtained from past experiences -- mines, collisions, missile EMP tests, and Falkland Island experiences. He discussed the new destroyer DDG 51 and its survivability design along with ship design tradeoff. Trends and needs for the future including innovative ideas and computer modeling tools were discussed. Captain Hering summarized his talk by noting that ship survivability is getting attention and that very reasonable action is being taken to improve survivability.

Mr. Otto Renius discussed survivability of mobile ground systems in the fourth paper. This was an interesting talk on the land based weapons. He discussed battlefield threats and showed how land offense is based on the tank. He noted that no tank

is invulnerable and discussed survivability needs -- reduced detection, hit avoidance, and penetration reduction. Aircraft are being used as an example. He discussed methods to avoid detection, a vehicle integrated defense system, laser threat warning, vehicle hardening, and full scale simulation facilities. He showed some of the ideas being discussed for future land vehicles and existing survivability gaps. Mr. Renius noted that future survivability systems will involve more than passive armor -- counter measures and hit avoidances will be introduced to make more survivable tanks.

Lt. Colonel Donald Gage gave the last talk on survivability -- "Survivability of Fixed Ground Systems." He discussed the programs and organizational structures required to manage the survivability aspects of weapons systems. Colonel Gage discussed the Air Force program acquisition life cycle including advanced development, engineering development, production, and operations. He discussed program requirements, an integrated approach to engineering management, trade off studies, test plans, and validation approaches. Colonel Gage discussed the strong emphasis on survivability of the Air Force, how to engineer survivability, and how to maintain and manage survivability.

#### ***The Elias Klein Memorial Lecture***

The fourth Elias Klein Memorial Lecture was given by Dr. Eric E. Ungar of Bolt Beranek and Newman on "Vibration Challenges in Microelectronics Manufacturing." Dr. Ungar discussed requirements in vibration control for electronic chip manufacturing facilities. He introduced the talk with a discussion on how chips are made and noted that line widths within chips approach the wavelength of light and that registration must be within 10 percent of line width. He showed facility requirements -- environment (low vibration and clean atmosphere), efficient space, process support, and air handling systems. A sample layout of these facilities was given. Dr. Ungar listed the major sources of vibration -- fans, turbulent air in ducts, pumps, liquid flow in pipes, foot fall, and in plant vehicles. He discussed the design of buildings for foot fall. Dr. Ungar discussed facility vibration criteria and showed examples of allowable vibration spectra and actual vibration spectra. He noted the problems with these criteria and considerations in

the development of facility criteria. The aspects of facility design including site selection, nonresponsive structures, building layout, source reduction, vibration isolation, and verification and diagnostic measurements were discussed. He noted that criteria for optical equipment were often inadequately known. He gave some conceptual sketches on the design of isolation systems for optical equipment and showed example transfer functions. In conclusion, Dr. Ungar discussed the challenge in the development of facility criteria that are realistic, mathematical transfer functions to obtain criteria, and the inclusion of structural dynamics in the design of equipment.

The second plenary talk was given by Mr. Gene M. Remmers of the David Taylor Naval Ship Research and Development Center on "The Evolution of Spectral Techniques in Navy Shock Design." This lecture was given in honor of Dr. Maurice Biot who applied the concepts of spectral analysis to structural response during earthquakes in his doctoral thesis in 1932. Mr. Remmers gave an interesting and comprehensive history of the evolution of spectral techniques in naval shock design. He started with the Biot work in 1932 where base motions were used to calculate maximum dynamic stress in buildings. Normal mode theory was used. He showed the nature of Biot's models and calculations with his later torsional pendulum analyzer. Mr. Remmers noted that the Biot era in earthquake work ended about the time the navy development began (1942) with Dr. Miller's reed gage. He discussed the envelope approach applied to navy shock design (1948), the fiducial limits of Blake (1954), serendipity shock spectrum dip of Belsheim and Blake (1957), and equipment interaction effects by O'Hara (1958). O'Hara showed that overdesign occurred in many cases. Mr. Remmers went on to discuss other developments such as factors which limit dynamic strength, effects of damping, effects of nearby structures, and yielding of materials.

The third plenary presentation was given by Messrs. John Mescall and Robert Fitzpatrick of the U.S. Army Materials and Mechanics Research Center on "Materials Implications of Advanced Thermal and Kinetic Energy Threats." Mr. Mescall discussed the classes of kinetic energy weapons and their penetration capabilities. He showed how strong shock waves propagate through solids and cause metals to fracture and the effects of heat treatment. Mathematical codes are now used to couple equations of state with

laws of motion -- the Hemp code was described. The experimental approach used at AMMRC was discussed along with examples. Mr. Mescall noted that we need to know more about the compression behavior of metals.

Mr. Robert Fitzpatrick discussed directed energy devices, countermeasures and counter countermeasures. He talked about lasers, particle beam weapons, and microwaves and showed how microwaves generate tremendous heat. Mr. Fitzpatrick discussed the implication of lasers in the modern battlefield and survivability and vulnerability issues. He noted that most conventional weapons are vulnerable and that structural damage could be done by high energy lasers. He discussed survivability and vulnerability of laser irradiated metals -- surface melting and hole boring, quench cracking, fatigue failure, and heat treatment and embrittlement.

#### ***Technical Program***

The formal technical program consisted of nine sessions containing full length papers and one session on short discussion topics. A session on machinery dynamics contained papers on rotor-bearing response, rotor blade response, nonlinear shaft couplings and a comparison of statistical energy analysis and finite element analysis predictions. Experimental results in high and low frequency ranges were discussed in the later paper.

A session on pyrotechnic shock measurement and simulation contained interesting papers on pyrotechnic shock flight experiences, pyrotechnic shock test and test simulation, strain histories associated with stage separation in systems using linear shaped charges, and the attenuation of pyrotechnic shock.

Vibration: test and criteria was the title of a session on accelerated random tests with nonlinear damping, vibration test environments for electronics, an automated vibration schedule for the development of wheeled and tracked vehicles, vibration isolation system development and modal testing techniques.

Shock testing and analysis was the subject of an interesting session containing papers on explosive driven shock tubes, shock wave calculations, the effect of measurement system phase response in shock spectrum computation, efficient algorithms

for calculating shock spectra, and evaluation and control of conservatism in shock tests.

A long but interesting session on damping contained much new technology. Modeling and experiments involving multi-impact dampers, hysteretic systems, turbine blade response, and materials were discussed.

The session on fluid/structure dynamics contained papers on piping, acoustic responses, analytical techniques, cavitation, random response, and nonlinear liquid sloshing.

Two sessions on dynamic analysis contained a number of interesting papers. The first session was devoted to papers on dynamic simulation of structural systems, experimental and analytical investigations of active landing gear loads, modal identification of multiple degree of freedom systems, random impact, and nuclear power plant seismic assessments. The second session contained papers on a modified Guyan reduction method, modal reduction techniques, face shear vibrations, and the dynamic behavior of composite layer beams.

A session on vehicle dynamics was new to the Symposium. It contained papers on off-road vehicles, motorcycle suspensions, shuttle environments, and computer-aided modeling and synthesis.

The Fifty-third Shock and Vibration Symposium was both technically informative and interesting yielding a large number of excellent papers. Again the plenary sessions with their overviews and philosophical insights added incomprehensible value to the meeting for new and experienced engineers. The Shock and Vibration Symposium continues to be the major annual event in this field and the SVIC can be congratulated for their continued maintenance of the quality of the technical presentations and the organization of interesting update lectures, overviews, and philosophical discussions so necessary for a complete meeting. Papers presented at the Symposium will be reviewed for quality of technical content and published in the 53rd SHOCK AND VIBRATION BULLETIN published by the SVIC.

The Symposium was concluded with successful tours of the environmental test facility at the Charles Stark Draper Laboratory and AMMRC -- dynamic testing and advanced prototyping facilities.

R.L.E.

# ABSTRACT CATEGORIES

## MECHANICAL SYSTEMS

Rotating Machines  
Reciprocating Machines  
Power Transmission Systems  
Metal Working and Forming  
Isolation and Absorption  
Electromechanical Systems  
Optical Systems  
Materials Handling Equipment

Tires and Wheels  
Blades  
Bearings  
Belts  
Gears  
Clutches  
Couplings  
Fasteners  
Linkages  
Valves  
Seals  
Cams

Vibration Excitation  
Thermal Excitation

## MECHANICAL PROPERTIES

Damping  
Fatigue  
Elasticity and Plasticity

## STRUCTURAL SYSTEMS

Bridges  
Buildings  
Towers  
Foundations  
Underground Structures  
Harbors and Dams  
Roads and Tracks  
Construction Equipment  
Pressure Vessels  
Power Plants  
Off-shore Structures

## STRUCTURAL COMPONENTS

Strings and Ropes  
Cables  
Bars and Rods  
Beams  
Cylinders  
Columns  
Frames and Arches  
Membranes, Films, and Webs  
Panels  
Plates  
Shells  
Rings  
Pipes and Tubes  
Ducts  
Building Components

## EXPERIMENTATION

Measurement and Analysis  
Dynamic Tests  
Scaling and Modeling  
Diagnostics  
Balancing  
Monitoring

## VEHICLE SYSTEMS

Ground Vehicles  
Ships  
Aircraft  
Missiles and Spacecraft

## ANALYSIS AND DESIGN

Analogs and Analog  
Computation  
Analytical Methods  
Modeling Techniques  
Nonlinear Analysis  
Numerical Methods  
Statistical Methods  
Parameter Identification  
Mobility/Impedance Methods  
Optimization Techniques  
Design Techniques  
Computer Programs

## BIOLOGICAL SYSTEMS

Human  
Animal

## ELECTRIC COMPONENTS

Controls (Switches, Circuit Breakers)  
Motors  
Generators  
Transformers  
Relays  
Electronic Components

## GENERAL TOPICS

Conference Proceedings  
Tutorials and Reviews  
Criteria, Standards, and  
Specifications  
Bibliographies  
Useful Applications

## MECHANICAL COMPONENTS

Absorbers and Isolators  
Springs

## DYNAMIC ENVIRONMENT

Acoustic Excitation  
Shock Excitation

# ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N-number. Doctoral dissertations are available from University Microfilms (DA), 313 N. Zeeb Rd., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, DC 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

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# MECHANICAL SYSTEMS

## ROTATING MACHINES

83-1

### Computer Method for Forced Torsional Vibration of Propulsive Shafting System of Marine Engine with or without Damping

J.-S. Wu and W.-H. Chen

Dept. of Naval Architecture and Marine Engrg., Natl. Cheng-Kung Univ., Taiwan, ROC, J. Ship Res., 26 (3), pp 176-189 (Sept 1982) 12 figs, 9 tables, 12 refs

**Key Words:** Shafts, Marine engines, Torsional vibration, Damping effects, Computer programs

In the preliminary design of a propulsive shafting system, the additional (vibratory) stress due to torsional vibration is one of the important factors that must be considered in addition to the mean stress induced by the steady torque. In this paper existing information concerning shaft design is reviewed; procedures formerly performed by slide rule, diagrams, and tabulations are formulated; and, based on the induced formulas, computer programs are developed. For an engine either two cycle or four cycle, single cylinder or multicylinder, and for a shafting system either undamped or damped (inner or outer or both inner and outer), it is required only to change the input data to obtain the desired data for various order numbers of torsional vibrations due to various firing orders of the cylinders. The output data include the natural frequencies and the corresponding mode shapes of the torsional vibrations, the amplitudes of twisting angles, and the vibratory stresses of the shafts. The reliability of the induced formulas and the developed computer programs has been confirmed by agreement between the computer output and existing information.

83-2

### Design Charts for Self-Excited Whirling Critical Speeds

H.P. Yagoda and J. Ketchman

AMF Corp., Stamford, CT, J. Ship Res., 26 (3), pp 190-208 (Sept 1982) 4 figs, 2 tables, 6 refs

**Key Words:** Shafts, Critical speeds, Whirling, Graphical analysis

Employing a generalized tailshaft model of the propulsion system, design charts are constructed for rapidly estimating self-excited whirling critical speeds of the shafting system over a wide range of design parameters. These design chart estimates may be refined to any desired accuracy by a program developed for a programmable hand calculator. The analysis includes propeller mass and rotatory inertia, propeller gyroscopic effects, shaft mass and flexural rigidity, and partial fixity of the line shafting at the forward bearing. Comparison of results with other methods is very favorable.

83-3

### Evaluation of Unstable Probability of Rotors Having Stiffness Errors of Asymmetry

T. Iwatsubo, K. Tomita, and R. Kawai

The Faculty of Engrg., Kobe Univ., Rokko, Nada, Kobe, Japan, Bull. JSME, 25 (206), pp 1299-1305 (Aug 1982) 11 figs, 7 refs

**Key Words:** Shafts, Vibration response, Monte Carlo method, Variable material properties

The bending stiffness of a shaft in a two pole generator is regarded as a random variable, thus the amplitude and the stability of a rotor system are statistically analyzed to seek the influence of the error of the bending stiffness on the system; thus the variance of amplitude of the rotor and the mode function due to the error are obtained. The probability of unstable vibration of the rotor system is predicted and compared with the results of the simulation of the Monte Carlo method.

83-4

### Forced Flexural Vibration of a Rotating Disc with Its Shaft Supported in Anisotropic Bearings with Gyroscopic Moments and Rotary Inertia under External and Internal Damping (Erzwungene Biegeschwingungen einer anisotrop gelagerten Scheibenwelle mit Kreiselwirkung und Drehträgheit, äusserer und innerer Dämpfung)

W. Kellenberger

BBC Aktiengesellschaft, Baden, Switzerland, Forsch. Ingenieurwesen, 48 (3), pp 65-73 (1982) 11 figs, 8 refs

(In German)

**Key Words:** Forced vibration, Flexural vibration, Shafts, Bearings, Anisotropy, Gyroscopic effects, Rotatory inertia effects, External damping, Internal damping

Forced vibration is studied for the case of a single-disc rotor on a flexible shaft mounted in flexible anisotropic bearings. Gyroscopic moments and polar moments of inertia are taken into account. Bearing damping proportional to speed is taken for external damping. For internal damping, a material damping is taken proportional to the speed in the rotating system, together with a structural damping which is independent of frequency. The excitation can be in the forward direction (unbalance) or backward, or can be a mixture of both (stationary, pulsating force). It is shown that the resonance amplitudes of the three critical speeds are very different.

### 83-5

#### **An Investigation of Rotor Harmonic Noise by the Use of Small Scale Wind Tunnel Models**

H. Sternfeld, Jr. and E.G. Schaffer

Boeing Vertol Co., Philadelphia, PA, Rept. No. NASA-CR-166337, 100 pp (Apr 1982)  
N82-24050

**Key Words:** Rotors, Helicopters, Noise measurement, Wind tunnel testing

Noise measurements of small scale helicopter rotor models were compared with noise measurements of full scale helicopters to determine what information about the full scale helicopters could be derived from noise measurements of small scale helicopter models. Comparisons were made of the discrete frequency (rotational) noise for 4 pairs of tests. Areas covered were tip speed effects, isolated rotor, tandem rotor, and main rotor/tail rotor interaction. Results show good comparison of noise trends with configuration and test condition changes, and good comparison of absolute noise measurements with the corrections used except for the isolated rotor case.

### 83-6

#### **Asynchronous Motor Simulation by a Digital Differential Analyser**

A. Baccigalupi and C. Sanges

Istituto Elettrotecnico, Università di Napoli, Naples, Italy, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 44-46, 2 figs, 4 refs

**Key Words:** Asynchronous motors, Digital simulation

This paper investigates the real mathematical model of an asynchronous machine allowing for stepped air-gap flux

density distribution. General purpose numerical computers are not always cost effective. In this paper a non-conventional solution method is analyzed using a digital differential analyzer, the PMICE. The usefulness of the PMICE in simulating complex and ill-conditioned problems is due to its special design, its high machine word length and the pipelining and parallel processing techniques involved.

### 83-7

#### **Computer Aided Analysis of Rotors Parametric Instabilities (Vibrations)**

J.M. Krodkiewski and Z.A. Parszewski

Univ. of Melbourne, Grattan Street, Parkville, Victoria 3052, Australia, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 183-186, 9 figs, 3 refs

**Key Words:** Rotors, Parametric vibration, Computer-aided techniques

Numerical computer-aided procedures are devised for finding parametric instability regions and parametric forced vibrations of real machine-support systems, with experimental receptance characteristics of the supporting structures. Computer executed plotting of instability regions boundaries and resonance diagrams, as well as journal loci, are presented.

### 83-8

#### **Gap-Narrowing Rings Make Booster Pumps Quiet at Low Flow**

E. Makay and D. Nass

Energy Res. and Consultants Corp., Power, 126 (9), pp 87-88 (Sept 1982) 5 figs, 4 refs

**Key Words:** Pumps, Centrifugal pumps, Axial vibration, Vibration control

A case history of axial vibration control of heavy duty horizontal single-stage double-suction centrifugal pumps at low-flow operation is discussed. Vibration was reduced by shortening the bearing length, introducing a force-feed lubrication into the pump, and reworking the rotor-clearance area by inserting stationary gap-reducing rings in the casing just beyond impeller shrouds.

## RECIPROCATING MACHINES

(See Nos. 174, 175, 188)

## METAL WORKING AND FORMING

83-9

### Source of Noise and Vibration in Idling Circular Saws and Its Control by Tooth Design

M.-C. Leu

Ph.D. Thesis, Univ. of California, Berkeley, CA, 125 pp (1981)

DA8212012

**Key Words:** Saws, Circular saws, Noise generation, Vibration excitation, Noise source identification

Experiments have been conducted to examine the often contradictory arguments surrounding the noise source in idling circular saws. Saw resonant vibration, which produces a high-frequency intense sound often called screaming noise, is shown to be aerodynamically excited rather than excited by mechanical sources. Blade resonance is caused by the interaction of the saw teeth with the surrounding air.

83-10

### A Method for Experimental Determination of Frequency Response for Mathematical Modelling and for the Determination of Response of Machine Tools (Eine Methode zur experimentellen Ermittlung von Nachgiebigkeitsfrequenzgängen als Grundlage einer rechnergestützten Modellierung und Verhaltensanalyse von Werkzeugmaschinen)

E. Jahn

Technische Universität Dresden, Sektion Fertigungstechnik und Werkzeugmaschinen, Maschinenbautechnik, 31 (8), pp 358-361 (Aug 1982) 6 figs, 9 refs (In German)

**Key Words:** Machine tools, Frequency response, Measurement techniques

A method for measuring periodic and aperiodic frequency response of machine tools is presented.

83-11

### Availability of Workplace Noise Control Technology for Selected Machines

R. Bruce, K. Eldred, C. Jokel, R. Potter, and D. Melone

Bolt, Beranek and Newman, Inc., Cambridge, MA, Rept. No. BBN-4330, EPA-550/9-81-321, 288 pp (May 1982)

PB82-219163

**Key Words:** Machine tools, Industrial facilities, Noise generation, Noise reduction

This report reviews the noise control technology available to equipment manufacturers and users of the following machines: automatic screw machines, semi-automatic stamping presses, planes, wood saws, metal saws, crawler tractors, molding machines, spinning frames, and twistors.

## ELECTROMECHANICAL SYSTEMS

(See No. 6)

## MATERIALS HANDLING EQUIPMENT

(Also see No. 206)

83-12

### Optimal Offsets for Vibrating Calender Stacks

E. Shuffler

Dominion Engineering Works, Ltd., P.O. Box 220, Montreal, Canada, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 180-182, 5 figs, 3 refs

**Key Words:** Calenders, Materials handling equipment, Vibration analysis

A calender stack can be modeled as a series of masses and springs. Each roll is a mass and the paper sheet running between them acts as a spring. The model can predict the natural modes of vibration of the stack and the relative amplitudes of roll displacement for each mode. By offsetting the rolls in a stack it is possible to reduce or eliminate the vibration due to a phenomenon called regenerative feedback. The model is used to compute optimal offsets which would minimize vibration and avoid barring problems of the type associated with this phenomenon.

# STRUCTURAL SYSTEMS

## BRIDGES

83-13

### Impact Factors (Dynamic Augmentation Factors) for Bridges on Indian Railways by Computer Simulation Studies - A Case Study

N. Ananthanarayana

Research, Designs & Standards Organisation, Government of India, Ministry of Railways, Manak Nagar, Lucknow, India, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 144-146, 4 figs, 3 refs

**Key Words:** Bridges, Railroads, Interaction: vehicle-structure, Computerized simulation

An investigation into the adequacy or inadequacy of the impact formula currently in use for bridges on Indian railways, and means of modifying same, was made. A computer simulation study was conducted aimed at an exhaustive analytical study of the vehicle-bridge dynamic system. The article describes briefly the computer simulation study, its validation and the practical impact factor proposed for bridge design.

83-14

### Mathematical Modelling of Bridge Structures for Dynamic Analysis

O.A. Pekau

Dept. of Civil Engrg., Concordia Univ., Montreal, Quebec, Canada H3G 1M8, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 255-257, 7 figs, 11 refs

**Key Words:** Bridges, Slabs, Beams, Natural frequencies, Mode shapes, Seismic analysis, Earthquake response, Traffic induced vibrations

A review is presented of the mathematical models currently available for the dynamic analysis of bridge structures. The various idealizations of bridge superstructures are described

together with associated analytical techniques suitable for loadings arising principally from vehicular traffic or the lateral actions of earthquake ground motions. Although emphasis is on mathematical modeling of bridge structures, computer techniques wherein the bridge is modeled by means of either finite strips or finite elements, are also described.

## BUILDINGS

(Also see Nos. 74, 103, 155)

83-15

### Parameter Estimation of a Building from Modal Data

J.-G. Béliveau and S. Chater

Faculté des sciences appliquées, Université de Sherbrooke, Sherbrooke, Québec, Canada J1K 2R1, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 263-265, 4 figs, 3 tables, 5 refs

**Key Words:** Buildings, Multistory buildings, Parameter identification technique, Resonant frequencies, Mode shapes

A mathematical model of a physical system -- in this case a building loaded laterally -- gives results which do not agree with the observed behavior. This is due to uncertainties in the parameters used or in the assumptions made in formulating the model. Data in the form of the lowest resonant frequencies and mode shapes are used to estimate parameters of a twelve story building. Linear algebraic relations are used to express the estimation scheme which is dependent on initial estimates and sensitivity of the measured quantities with respect to the parameters.

83-16

### Control of Tall Buildings under Earthquake Excitation

J.N. Yang

Dept. of Civil, Mech., and Environmental Engrg., The George Washington Univ., Washington, DC 20052, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 833-849 (Oct 1982) 8 figs, 24 refs

**Key Words:** Buildings, Earthquakes, Active damping, Active control

A method of analysis for tall buildings implemented by active control systems and excited by earthquake ground

motions is proposed. The effectiveness of the active mass damper and the active tendon system is investigated. Demonstrations show that both control systems can be used to substantially reduce the response of tall buildings under strong earthquake excitations, if the control parameters are designed appropriately. Numerical examples for two tall buildings are worked out to demonstrate the feasibility of active control systems.

### 83-17

#### **Assessment of Structural Damage Using the Theory of Evidence**

S. Toussi and J.T.P. Yao

School of Civil Engrg., Purdue Univ., Lafayette, IN, Rept. No. CE-STR-82-12, NSF/CEE-82006, 40 pp (Mar 1982)  
PB82-215831

**Key Words:** Buildings, Dynamic tests, Damage

Dynamic test data of building structures are analyzed to assess structural damage and the method of converting evidential information to the interval representation of Dempster and Shafer is applied. It is shown how results obtained from individual sources are interpreted. Response histories, crack patterns, hysteretic behaviors, and the formation of damage parameter mass distributions are considered.

### 83-18

#### **Blast Capacity Evaluation of a Strengthened Steel Building**

F.E. Sock, N. Dobbs, W. Stea, and K. Shah

Ammann and Whitney, NY, Rept. No. ARLCD-CR-81059, SBI-AD-E400764, 151 pp (Jan 1982)  
AD-A114 540

**Key Words:** Buildings, Steel, Blast resistant structures, Dynamic tests

A series of dynamic tests were performed on a specially designed strengthened-steel building for use in Army ammunition plants. Test results indicated that the building can resist approximately 48.3 kPA (7.0 psi) of blast overpressures.

### 83-19

#### **Flexible Sleeved-Pile Foundations for Seismic Design**

J.M. Biggs

Dept. of Civil Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. R82-04, NSF/CEE-82005, 74 pp (Mar 1982)  
PB82-215724

**Key Words:** Buildings, Flexible foundations, Seismic design, Springs

The feasibility of constructing buildings on horizontally flexible foundations to mitigate the effects of earthquakes is investigated. The flexibility is achieved by inserting a soft spring between the building superstructure and the soil foundation. The use of slender piles enclosed in sleeves is found to permit flexural distortion. The piles are designed by a simple procedure using smoothed response spectra. The performance of building-foundation systems so designed are then studied using histories of actual ground motions. It is shown that the simple design procedure is adequate and that the concept achieves the desired result of greatly reducing seismic forces.

### 83-20

#### **Simplified Dynamic Analysis of Buildings with Basements**

T. Balendra, Y.-P. Tan, and S.-L. Lee

Dept. of Civil Engrg., National Univ. of Singapore, Kent Ridge, Singapore, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 895-914 (Oct 1982) 11 figs, 5 tables, 23 refs

**Key Words:** Buildings, Interaction: soil-structure, Interaction: structure-foundation

The effects of basements on the dynamic soil-structure interaction of buildings are investigated, and simplified models in which each interaction force is represented by a set of spring and dashpot in parallel are proposed. The frequency independent stiffness and damping coefficients to be used in the simplified models are obtained from transient analyses by comparing the average work done and the average rate of energy dissipated by the interaction forces in a more accurate lumped parameter model and the simplified model.

## **FOUNDATIONS**

### 83-21

#### **Mechanics of Three-Dimensional Soil-Structure Interaction**

C.S. Desai, H.V. Phan, and J.V. Perumpral

Dept. of Civil Engrg. and Engrg. Mech., Univ. of Arizona, Tucson, AZ, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 731-747 (Oct 1982) 11 figs, 1 table, 20 refs

**Key Words:** Interaction: soil-structure

A finite element procedure for the general problem of three-dimensional soil-structure interaction involving nonlinearities caused by material behavior, geometrical changes, and interface behavior is presented. The formulation is based on the updated Lagrangian or approximate Eulerian approach with appropriate provision for constitutive laws. Consideration is given to the mathematical and experimental aspects related to the important topic of development and adoption of a constitutive law for the geologic medium. Development and use of an interface element to describe the three-dimensional interface behavior are described.

### 83-22

#### **Experimental Observations of the Effect of Foundation Embedment on Structural Response**

A.N. Lin

Ph.D. Thesis, California Inst. of Tech., 337 pp (1982)  
DA8218960

**Key Words:** Foundations, Interaction: soil-structure, Forced vibration, Stiffness coefficients, Damping coefficients

Ambient, ring-down, and forced vibration tests were used to determine the effect of foundation embedment on the response of a one-story model structure 10 ft. square in plan and 11.4 ft. high. The tests, conducted at the full-, half-, and unembedded foundation conditions, led to the identification of the fundamental translatory mode in the primary (east-west) and secondary (north-south) directions, and two torsional modes. The forced vibration consisted of horizontally incident SH-waves generated as an excitation structure located 47.5 ft. (center-to-center) away. During these tests, detailed measurements of the near-field ground motion and modal displacement ratios were obtained at the fundamental mode in the primary direction.

## **UNDERGROUND STRUCTURES**

### 83-23

#### **Structural Behavior and Design Implications of Concrete Tunnel Linings Based on Model Tests and Parameter Studies**

G.E. Sgouros

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 405 pp (1982)  
DA8218559

**Key Words:** Tunnel linings, Concretes, Interaction: soil-structure

The objective of this study was to investigate the structural behavior of concrete tunnel linings at ultimate and service loads (with the emphasis on subway tunnels), taking into account soil-structure interaction and the nonlinearity of the concrete. The conclusions drawn could serve as the basis for the formulation of rational design guidelines for concrete tunnel linings in a wide range of ground conditions. The research consisted of an evaluation of concrete tunnel lining design practice in the United States, a series of model tests on arched and circular linings and the use of a finite element program to simulate the tests and to study the effects of the variation of certain parameters on full-scale linings.

## **HARBORS AND DAMS**

### 83-24

#### **Safety Analysis of High Hazard Deteriorating Concrete Gravity Dam-Reservoir Systems Including Corrective Measure - Earthquake and Dynamic Study**

C.Y. Yang, V. Chiarito, and P. Dressel

Water Resources Ctr., Univ. of Delaware, Newark, DE, Rept. No. W82-05296, OWRT-A-047-DEL(4), 113 pp (Oct 1981)  
PB82-224718

**Key Words:** Dams, Concretes, Earthquake damage

Research was carried out to analyze the safety of high-hazard deteriorating concrete gravity dam-reservoir systems against earthquakes. Due to the uncertainty in earthquake occurrence and magnitude, a probabilistic approach to the dam-reservoir-earthquake problem was sought. Design and analysis based on probability concepts were worked out in detail.

## **CONSTRUCTION EQUIPMENT**

### 83-25

#### **Substrategy for Construction Site Noise Abatement**

P.U. Pawlik

Office of Noise Abatement and Control, EPA, Washington, DC, Rept. No. EPA-550/9-82-151, 49 pp (Aug 1981)  
PB82-218579

**Key Words:** Noise reduction, Construction equipment

This study outlines a national strategy to address construction site noise. After explaining the peculiar nature of construction-site noise and estimating the population exposed to high noise levels, the author presents viable methods to control such noise.

## PRESSURE VESSELS

83-26

### Fatigue-Crack Growth Correlations for Design and Analysis of Stainless Steel Components

L.A. James

Westinghouse Hanford Co., Richland, WA, ASME Paper No. 82-PVP-25

**Key Words:** Pressure vessels, Piping systems, Steel, Fatigue life

The objective of this paper is to collect much of the existing crack growth data on austenitic steels, analyze it in a consistent manner, and present it in a form useful for LEFM analyses of pressure vessel and piping components.

## POWER PLANTS

(Also see Nos. 91, 106, 125, 126, 127)

83-27

### Automobile Impact Forces on Concrete Wall Panels

R.L. Chiapetta and E.C. Pang

Chiapetta, Welch and Associates, Ltd., Palos Hills, IL, Rept. No. CWA-4010-FR, 262 pp (June 1982)  
NUREG/CR-2790

**Key Words:** Nuclear power plants, Concretes, Collision research (automotive), Interaction: vehicle-structure, Impact response

The objective of this study was to develop force-time impact signature data for use in the design or evaluation of nuclear power plant structures subject to tornado-borne automotive

vehicle impact. The approach was based on the use of analytical vehicle models to calculate impact forces.

83-28

### Three Dimensional Structure to Structure Interaction Analyses

S.N. Mukherjee

Brown Boveri & Cie, 5400 Baden, Switzerland, Nucl. Engrg. Des., 70 (1), pp 45-56 (June 1982)  
19 figs, 7 refs

**Key Words:** Nuclear power plants, Seismic analysis, Interaction: soil-structure

This paper presents a report on structure to structure interaction in three dimensional configuration. The analysis takes into consideration the layered soil media extended to bed-rock level having different material properties. The soil is modeled using three dimensional isoparametric finite elements. The structural complex; i.e., reactor-building, turbine-building, electrical-building and service-building are modeled according to modal equivalent method, in which only the significant free vibration modes are taken into consideration. The free vibration modes are calculated using fixed base structures.

83-29

### Compilation of Data Concerning Known and Suspected Water Hammer Events in Nuclear Power Plants (CY 1969 - May 1981)

R.L. Chapman, D.D. Christensen, R.E. Dafoe, O.M. Hanner, and M.E. Wells

EG and G Idaho, Inc., Idaho Falls, ID, Rept. No. EGG-CAAD-5629, 295 pp (May 1982)  
NUREG/CR-2059

**Key Words:** Nuclear power plants, Water hammer, Data presentation

This report compiles data concerning known and suspected water hammer events reported by BWR and PWR nuclear power plants in the United States from January 1969 to May 1981. This information is summarized for each event and is tabulated for all events by plant, plant type, year of occurrence, type of water hammer, system affected, basis/cause for the event, and damage incurred.

83-30

**Dynamic Combinations for Mark II Containment Structures**

A.J. Philippacopoulos and M. Reich  
Brookhaven Natl. Lab., Upton, NY, Rept. No. BNL-  
NUREG-51366, 176 pp (June 1982)  
NUREG/CR-2039

**Key Words:** Nuclear reactor containment, Finite element technique, Interaction: soil-structure

The behavior of a representative Mark II containment is investigated with respect to its structural capacity when subjected to various load combinations that may be expected during its lifetime. Mathematical models based on finite element idealization procedures are developed and verified. These include three-dimensional finite models and the so-called stick models of the Mark II containment system. The latter are employed for soil-structure interaction analysis. Various BNL computer codes are utilized to evaluate structural responses.

83-31

**Investigation of Reactor Dynamics by Fluctuation Methods Using a Deconvolution Technique**

G.T. Ibrahim  
Ph.D. Thesis, North Carolina State Univ. at Raleigh,  
107 pp (1982)  
DA8217035

**Key Words:** Nuclear reactors, Deconvolution technique, Nuclear power plants

Information about the dynamic behavior of a power reactor may lie in the amplitude modulation waveforms of some of the reactor noise signal components. This information may help in better understanding the dynamic behavior of the reactor. The noise signal component of interest is filtered from a wide spectrum of potentially unwanted signals. Consequently the amplitude modulation waveform of the signal of interest is distorted. In order to recover the information lost by the filter distortion, the amplitude waveform of the signal of interest is deconvolved with the amplitude modulation waveform of the filter response (amplitude impulse response). A direct and easily implemented deconvolution technique is used.

83-32

**Development of Engineering Codes of Practice for Corrosion Fatigue**

P.M. Scott, A.J.E. Foreman, and B. Tomkins

Materials Development Div., Harwell, UK, ASME  
Paper No. 82-PVP-30

**Key Words:** Corrosion, Fatigue life, Nuclear reactor components, Pressure vessels, Steel

The recognition that time-dependent effects of aqueous corrosion can have a large influence on fatigue failure in structural steels for nuclear reactor pressure vessels is having an important influence on the continuing process of revision and improvement of design and inspection codes. The contrasting requirements of engineering codes for design purposes or for in-service inspection purposes are discussed. The critical assumptions in each are highlighted and illustrated with examples incorporating recent improvements in the mechanistic understanding of the development of corrosion fatigue failure.

83-33

**Power System Dynamic Stability Limits Considering the Effects of Non-Linear Loads**

N. Martins and R.M. Stephan  
CEPEL, Cidade Universitária - Rio de Janeiro, Brazil,  
System Simulation and Scientific Computation,  
Proc. of the 10th IMACS World Congress, Aug 8-13,  
1982, Montreal, Canada, Vol. 3, pp 120-122, 2 figs,  
7 refs

**Key Words:** Power plants (facilities), Electromechanical damping, Computer programs, Eigenvalue problems, Stability

This paper describes some features of a package of programs developed for the analysis of small-disturbance electromechanical stability of power systems. All the relevant power system components can be represented in these programs. Some features of the algorithms employed by these programs are described. Comments are also made on aspects such as state matrix sparsity, the practical value of eigenvalue sensitivity coefficients and on some of the present algorithmic needs in the area of small-disturbance stability of large power systems.

## OFF-SHORE STRUCTURES

83-34

**Shaking Table Tests of a Tubular Steel Frame Model**

Y. Ghanaat and R.W. Clough  
Earthquake Engrg. Res. Ctr., Univ. of California,

Berkeley, CA, Rept. No. UCB/EERC-82/02, NSF/CEE-82011, 149 pp (Jan 1982)  
PB82-220161

**Key Words:** Off-shore structures, Drilling platforms, Dynamic tests, Seismic response

This report presents the experimental results of a two dimensional x-braced tubular steel offshore platform model subjected to shaking table motions simulating earthquake excitations. The main purpose of this research was to measure the dynamic response and failure mechanism to be expected of a typical offshore frame subjected to damaging earthquake motions.

**83-35**

**Hybrid Simulation of a Tanker Moored at a Single Point Subjected to Effects of Wind, Current and Waves**

A. Glumineau and R. Mezencev  
E.N.S.M., Université de Nantes, France, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 98-100, 3 figs, 3 refs

**Key Words:** Tanker ships, Moorings, Off-shore structures, Wind-induced excitation, Fluid-induced excitation, Hybrid simulation

The exploitation of offshore oilfields raises the problem of transporting the production. In general, the solution is to use tankers of from 250,000 to 500,000 tdw. During loading, the tanker is moored at a single point and is subject to the effects of the elements of wind, current and waves. In order to study the problem posed by such mooring, a simulation was carried out using a hybrid computer with a model accounting for the influence of wind, waves and current as well as that of the machines. The expression of hydrodynamic forces was formulated using the perfect fluid theory to give the coupling of translation and rotation movements.

**83-36**

**Environmental Loading and Response**

E.C. Bowers and R.G. Standing  
National Maritime Inst., Feltham, UK, Rept. No. NMI/R-135, OT-M-8219, 30 pp (1982)  
PB82-226812

**Key Words:** Off-shore structures, Wave forces, Wind-induced excitation

Environmental forces on offshore structures are caused by a combination of wind, waves and current. Of these three components, wave forces are the most complex. Separate effects of wind, waves and current are discussed, as well as coupling between waves and currents and the combined effect of all three on moored structures. Various typical motions of moored structures and their moorings are used as a means of introducing the environmental forces, and comments are made on the ability of physical and mathematical models to describe the physics involved. Tethered buoyant platforms and single point moorings are used to illustrate the various types of response and associated design problems.

## VEHICLE SYSTEMS

### GROUND VEHICLES

(Also see No. 81)

**83-37**

**Frequency Response Characteristics of Military Vehicles**

R.A. Weiss  
Geotechnical Lab., Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES/MP/GL-82-6, 61 pp (Apr 1982)  
AD-A115 660

**Key Words:** Ground vehicles, Military vehicles, Frequency response, Off-highway vehicles, Interaction: vehicle-terrain

Empirical frequency response characteristics are calculated from the dynamic response data obtained from vehicles that are crossing obstacles. The frequency response signature for a vehicle is essentially the ratio of the power spectrum of the dynamic response of a vehicle to the power spectrum of the terrain feature producing the response. This study determines the acceleration frequency response signatures by calculating the Fourier series representation of the acceleration measured at a point on the vehicle as it crosses an obstacle and the Fourier series representation of the obstacle profile. The Fourier series representation of the measured acceleration is obtained by the fast Fourier transform algorithm. A numerical analysis was done for the M114 track vehicle.

**83-38**

**Demonstration Truck Program 1. Program Summary: Truck Noise Reduction**

E.K. Bender and J.A. Kane  
Bolt, Beranek and Newman, Inc., Cambridge, MA,  
Rept. No. BBN-4839, EPA-550/9-82-331A, 61 pp  
(Dec 1981)  
PB82-220328

**Key Words:** Trucks, Diesel engines, Noise reduction

This report presents a comprehensive overview of an EPA-sponsored program to demonstrate the technology and costs of reducing the noise of four heavy-duty diesel trucks to 72 dBA. The program comprised engineering development and service evaluation phases. Noise control treatments were developed and installed on each truck to reduce its noise to the target level. The treatments included partial engine and transmission enclosures, exhaust silencing systems, and two-stage engine mounts.

### 83-39

#### **Demonstration Truck Program 2. Noise Reduction Technology and Costs for a Ford CLT 9000 Heavy-Duty Diesel Truck**

E.K. Bender, J.W. Ernest, and J.A. Kane  
Bolt, Beranek and Newman, Inc., Cambridge, MA,  
Rept. No. BBN-4379, EPA-550/9-82-331B, 66 pp  
(Oct 1981)  
PB82-220336

**Key Words:** Trucks, Diesel engines, Noise reduction

This report discusses the technology and costs required to reduce the noise of a Ford CLT 9000 heavy-duty diesel truck from 77.1 to 72.3 dBA. The noise control treatment consists primarily of a dual exhaust silencing system and a partial enclosure for the engine and transmission.

### 83-40

#### **Demonstration Truck Program 3. Noise Reduction Technology and Costs for a General Motors Brigadier Heavy-Duty Diesel Truck**

E.K. Bender, J.A. Kane, and P.J. Remington  
Bolt, Beranek and Newman, Inc., Cambridge, MA,  
Rept. No. BBN-4507, EPA-550/9-82-331C, 72 pp  
(Oct 1981)  
PB82-220344

**Key Words:** Trucks, Diesel engines, Noise reduction

This report discusses the technology and costs required to reduce the noise of a General Motors Brigadier heavy-duty

diesel truck from 81.7 to 71.6 dBA. The noise control treatment consists primarily of a dual exhaust silencing system and a partial enclosure for the engine and transmission.

### 83-41

#### **Demonstration Truck Program 4. Noise Reduction Technology and Costs for an International Harvester F-4370 Heavy-Duty Diesel Truck**

E.K. Bender, R.L. Bronsdon, J.A. Kane, and P.J. Remington  
Bolt, Beranek and Newman, Inc., Cambridge, MA,  
Rept. No. BBN-4667, EPA-550/9-82-331D, 94 pp  
(Oct 1981)  
PB82-220351

**Key Words:** Trucks, Diesel engines, Noise reduction

This report discusses the technology and costs required to reduce the noise of an International Harvester F-4370 heavy-duty diesel truck from 81.1 to 72.2 dBA. The noise control treatment consists primarily of a dual exhaust silencing system and a partial enclosure for the engine and transmission.

### 83-42

#### **Demonstration Truck Program 5. Noise Reduction Technology and Costs for a Mack R686 Heavy-Duty Diesel Truck**

E.K. Bender, J.A. Kane, and P.J. Remington  
Bolt, Beranek and Newman, Inc., Cambridge, MA,  
Rept. No. BBN-4795, EPA-550/9-82-331E, 120 pp  
(Dec 1981)  
PB82-220369

**Key Words:** Trucks, Diesel engines, Noise reduction

This report discusses the technology and costs required to reduce the noise of a Mack R686 heavy-duty diesel truck from 81.6 dBA to 73.2 dBA. The noise control treatments consist primarily of a partial enclosure for the engine and transmission, an exhaust silencing system, and two-stage engine mounts.

### 83-43

#### **A Bond-Graph Computer Model to Simulate the 3-D Dynamic Behaviour of a Heavy Truck**

H.B. Pacejka and C.G.M. Tol

Delft Univ. of Tech., Dept. of Mech. Engrg., Delft, The Netherlands, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 398-401, 10 figs, 3 refs

**Key Words:** Ground vehicles, Automobiles, Trucks, Bond graph technique

The development of bond graph models useful for vehicle dynamics studies are demonstrated. Models of increasing complexity are shown from a simple model for the horizontal motions of an automobile to a three-dimensional model particularly suited for studies of truck motions.

### 83-44

#### **Numerical Synthesis of Dynamic Equations of Motion and Their Application to a Crawler Tractor**

Z. Goraj and E. Igras

Institute of Aircraft Engrg. and Appl. Mech., Polytechnic of Warsaw, 00-665, Warsaw, ul. Nowowiejska 24, Poland, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 142-144, 3 figs, 4 refs

**Key Words:** Tractors, Equations of motion, Numerical analysis

The numerical method for synthesis of dynamic equations of motion in systems with many degrees of freedom and complicated kinematics of motion is presented in detail. The method was applied to a crawler tractor in order to obtain dynamic equations of motion. Accelerations and inner dynamic reactions, derived from numerical solution of equations of motion, were used as input for a finite-element program in order to calculate dynamic state of stress and strain in chosen elements of a structure.

### 83-45

#### **A Comparison of Accident Characteristics and Rates for Combination Vehicles with One or Two Trailers**

T. Chirachavala and J. O'Day

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-81-41-REV, 91 pp (May 11, 1982)  
PB82-209412

**Key Words:** Collision research (automotive), Trailers, Articulated vehicles

Accident involvement rates for tractors with single trailers are compared with rates for tractors with more than one trailer. Major differences in the distributions of vehicle, driver, operating, and environmental factors for the two types of vehicles are noted, and a multivariate analysis is presented for those factors which are common in the accident and exposure data sets.

### 83-46

#### **Longitudinal Oscillations of Vehicle/Trailer Combinations Induced by Overrun Braking**

R.S. Sharp

Mech. Engrg. Dept., Univ. of Leeds, Leeds, LS2 9JT, UK, Vehicle Syst. Dynam., 11 (1), pp 43-61 (Feb 1982) 11 figs, 4 refs

**Key Words:** Ground vehicles, Articulated vehicles, Longitudinal vibration, Braking effects

A mathematical model for the representation of longitudinal oscillations which can occur in car/trailer systems in braking, when the trailer brakes are applied through compression of the towing hitch, is described. The model is used to show how the trailer braking system parameters affect the steady deceleration performance of the vehicle combination, and the stability, in the linear system sense, of the steady motions. The sensitivity of the stability to other system design parameters is also examined. Digital simulation of the motions occurring in response to a step input of car braking torque is reported, with the results confirming the predictions of the linear stability analysis, and also showing the influence of backlash in the trailer brake actuating mechanism.

### 83-47

#### **Dynamical Analysis of a Simple Vehicle on a Periodic Guideway**

K. Popp, A. Kraus, and T. Heiss

Institut f. Mechanik, Tech. Univ. Munchen, Munich, Germany, Vehicle Syst. Dynam., 11 (2), pp 107-120 (Apr 1982) 7 figs, 10 refs

**Key Words:** Guideways, Interaction: vehicle-guideway

The dominant vertical motions of a simple vehicle traveling on a flexible periodic guideway is investigated. The mathematical model leads to a state equation with periodic coeffi-

clients and periodically jumping states. The aim of the paper is the dynamic analysis of the vehicle-guideway system with respect to stability, guideway deflections and vehicle accelerations. As alternative to the common simulation technique, the analytical solution based on Floquet theory is applied. Both methods are implemented in a computer program and used to perform a detailed parameter study which shows the dependence of the dynamical system behavior on the non-dimensional system parameters.

**83-48**

**To the Running of Bogies with Compound Drive and Different Diameters**

O. Krettek

Lehr- und Forschungsgebiet, Analytische Verfahren in Fahrzeug und Transporttechnik, Univ. of Aachen, Germany, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 147-149, 4 figs

**Key Words:** Tramways, Railroad trains, Cornering effects, Noise generation

Bogies with kinematic coupled axles, as found in modern tramways, tend to oblique run if there are differences in wheel diameters. The size of the turning angle is defined by the differences in diameters and by the moment of the motor. The result is a very noisy run at high speed.

**83-49**

**Computer Simulation Study on Lateral Dynamics of Automated Guideway Transit Vehicle**

M. Abe

Dept. of Mech. Engrg., IKUTOKU Technical Univ., 1030 Shimoogino, Atsugi-shi, Kanagawa, Japan, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 141-143, 9 figs, 3 refs

**Key Words:** Automated transportation systems, Lateral response, Steering effects, Computerized simulation

Introducing a nonlinear, 7 degree-of-freedom dynamic model, a computer simulation study on the lateral motion of the AGT vehicle running on a straight or a curved guideway with and without guideway irregularities has been carried out to analyze the effects of the steering parameters on the vehicle lateral motion.

**83-50**

**Limiting Forces on Transit Trucks in Steady-State Curving**

R. Greif and H. Weinstock

Transportation Systems Ctr., Cambridge, MA, Rept. No. DOT-TSC-UMTA-81-69, UMTA-MA-06-0025-82-1, 52 pp (May 1982)  
PB82-227398

**Key Words:** Trucks, Railroad cars, Interaction: rail-wheel, Cornering effects

This study develops conservative bounds on wheel/rail forces and flange forces for several types of rigid and flexible trucks in steady-state curving conditions. The approximate analysis presented provides closed-form relations for estimating forces, truck angle of attack, creep force saturation and sliding conditions as a function of truck geometry and track parameters.

**83-51**

**Remarks on the Theory of Vehicle Vibrational Analysis Based on the On-the-Road Measurements**

M. Apetaur

Faculty of Mech. Engrg., Tech. Univ. of Prague, Vehicle Syst. Dynam., 11 (3), pp 143-173 (July 1982)  
21 figs, 10 refs

**Key Words:** Ground vehicles, Power spectral density, Vibration analysis

Basic relation between input spectral density matrix and output spectral density matrix of a linear stochastically excited dynamic system is indicated. General conclusions regarding the output processes spectral densities, coherences and phase angles in respect to the input processes stochastic properties are drawn. The possibility of the determination of the system's transfer functions when input and output spectral density matrices are known is discussed.

**83-52**

**Characterization of the Dynamic Roadway-Powered Electric-Vehicle System**

J.D. Salisbury, D. Mullenhoff, and C.E. Walter  
Lawrence Livermore Natl. Lab., CA, Rept. No. UCID-19272, 22 pp (Oct 1981)  
DE82007149

**Key Words:** Electric vehicles, Roadway powered electric vehicles, Dynamic tests, Experimental test data

Most of the preliminary measurements contained in this report were made to characterize the losses in the roadway and the pickup of the dynamic RPEV system. By analysis of power, voltage, current and impedance-bridge measurements, the equivalent series resistance and equivalent parallel resistance of the roadway and pickup inductances and capacitances were derived.

### 83-53

#### **Rail Transit Train/Elevated Structure Dynamic Interactions**

D.N. Wormley, M.L. Nagurka, and G. Isaacs  
Dept. of Mech. Engrg., Massachusetts Inst. of Tech.,  
Cambridge, MA, Rept. No. UMTA-MA-06-0096-  
82-1, 106 pp (Dec 1981)  
PB82-232166

**Key Words:** Elevated railroads, Interaction: vehicle-structure, Railroad trains

This study effort concentrated upon the interaction between multiple car transit trains and elevated structures typical of a transit system. The main objective of this study is to determine the dynamic impact factors generated by the vehicle train crossing the span and the accelerations in the vehicles generated by span motion. A dynamic interaction model has been formulated for multicar trains of vehicles traversing elevated span guideways.

### 83-54

#### **Anthology of Rail Dynamics Research**

S.E. Shladover  
Systems Control Technology, Inc., Palo Alto, CA,  
Rept. No. FRA/ORD-82/37, 36 pp (June 1982)  
PB82-217993

**Key Words:** Railroads, Interaction: rail-wheel, Reviews

This report is intended to provide the railroad industry and other interested parties with an anthology of recent technical information of long term value which has resulted from FRA-sponsored studies of rail system dynamics. This anthology includes brief descriptions of FRA contract reports and professional papers based on FRA contract work in the areas of wheel-rail interface phenomena, track characteristics, vehicle dynamics, vehicle-track interactions, longitudinal train dynamics, train resistance and lading response. A comprehensive bibliography of these documents is included.

### 83-55

#### **Handbook of Urban Rail Noise and Vibration Control: Executive Digest**

H.J. Saurenman, J.T. Nelson, and G.P. Wilson  
Wilson, Ihrig and Associates, Inc., Oakland, CA,  
Rept. No. UMTA-MA-06-0099-82-2, DOT-TSC-UM  
TA-81-73, 58 pp (Feb 1982)  
PB82-220427

**Key Words:** Rail transportation, Traffic noise, Urban noise, Vibration control, Noise reduction, Manuals and handbooks

This executive digest presents a summary of the information that is contained in the Handbook of Urban Rail Noise and Vibration Control. The handbook is a comprehensive review of the state-of-the-art in the field. The digest is intended for all those who would like an overview of the handbook's contents, either as an introduction to the handbook or as a source of information in and of itself. The text provides information useful in integrating noise and vibration control into transit system planning and operations. The tables, which follow the text, summarize technical information contained in the handbook on control treatments for way-side, vehicle, station, and groundborne noise and vibration.

### 83-56

#### **The Lateral Behaviour of a Two-Axled Railway Vehicle**

A.D. de Pater  
Delft Univ. of Tech., 2628 CD Delft, The Netherlands, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 133-134, 3 refs

**Key Words:** Railroad trains, Lateral response, Cornering effects, Stability

The most important factors which influence the lateral behavior of a symmetrical two-axled railway vehicle in the linear case are discussed. Mention is made of the Wickens' condition for perfect curving and stability behavior.

### 83-57

#### **Review and Summary of Computer Programs for Railway Vehicle Dynamics**

N.T. Tsai and W.D. Pilkey  
Office of Res. and Dev., Fed. Railroad Admn., Washington, DC 20590, System Simulation and Scientific

Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 130-132, 1 table, 15 refs

**Key Words:** Railroad trains, Computer programs, Reviews, Lateral response, Cornering effects, Interaction: rail-wheel

This paper presents the results of a recent review and collation of existing computer programs in rail vehicle dynamics. It provides guidance for selecting the proper programs to meet the special needs of each user. The computer programs are divided into the following groups: lateral stability, curving dynamics, train dynamics, wheel/rail contact, and those programs that do not fall into any other group. The review covers the software, modeling, and application aspects of each program.

**83-58**

**Dynamic Wheel Loads of Rolling Stocks**

D. Deepak

Joint Director Res. Track, Ministry of Railways, R.D.S.O., Lucknow 226011, U.P. India, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 150-153, 2 figs, 10 refs

**Key Words:** Railroad trains, High speed transportation systems, Interaction: rail-wheel

Theoretical analysis to estimate wheel load fluctuations of high speed railway vehicles running on rough welded tracks is presented. The effect of various track and vehicle parameters on wheel load variations is studied. It is found that track stiffness, track damping, track roughness and unsuspended masses are the major parameters that affect the dynamic wheel load variations at high speeds. A simple formula for design office is derived.

**83-59**

**A Non-Linear, Steady-State Curving Model for Steerable-Axle Railway Vehicles**

R.J. Anderson

Dept. of Mech. Engrg., McLaughlin Hall, Queen's Univ., Kingston, Ontario K7L 3N6, Canada, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 138-140, 3 figs, 2 refs

**Key Words:** Railroad trains, Cornering effects, Computer programs

A method for modeling the steady-state curving performance of steerable-axle railway vehicles is described. The model presented here uses methods which permit simulations of the steady curving performance of any rail vehicle to be produced quickly and efficiently with a minimum of effort. As the model is primarily a design tool, it is structured to provide the user with detailed design information related to wheel/rail interaction and the structural loads throughout the vehicle during curve negotiation.

**83-60**

**Simulation Model of Longitudinal Train Dynamics**

A.F. D'Souza and V.K. Garg

Illinois Inst. of Tech., Chicago, IL, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 5, pp 36-41, 9 figs, 15 refs

**Key Words:** Railroad cars, Impact response, Longitudinal response

This paper presents an interactive simulation model of longitudinal train dynamics. The model considers only the surge motion where each vehicle is assigned a single degree of freedom in the longitudinal direction. A description is given of modeling the various longitudinal forces acting on a vehicle in a train consist. Several forward integration techniques are employed and compared regarding their numerical stability and computer time. Interactive computer graphics are employed to display the simulation results.

**83-61**

**Numerical Simulation of the Dynamic Behavior of a Railway-Car with Nine Degrees of Freedom**

J.A. Richard

Institut Universitaire de Technologie, Cachan, France, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 135-137, 5 figs, 5 refs

**Key Words:** Railroad cars, High speed transportation systems, Multidegree of freedom systems, Critical speeds

The dynamic behavior of a high speed free truck or railway carriage running on a track is tabulated in full matrix  $A(7,7)$

for a truck and A (17, 17) for a railway carriage. For a reduction of the number of degrees of freedom, a truck with a half car-body is considered. By changing parameters, the number of degrees of freedom of the new mechanical system is reduced to nine. The results obtained are compared with those given by previous studies.

### 83-62

#### **Static and Dynamic Stability of Unsymmetric Two-Axle Railway Vehicles Possessing Perfect Steering**

A.H. Wickens

The Railway Technical Centre, Derby, UK, Vehicle Syst. Dynam., 11 (2), pp 89-106 (Apr 1982) 7 figs, 7 refs

**Key Words:** Railroad cars, Wheelsets, Stability

For railway vehicles having coned wheels mounted on solid axles, there is a conflict between the stability of lateral deviations from the motion along the track and the ability to steer round curves. A general theory is developed for the two-axle vehicle in which there is a lack of symmetry, fore-and-aft, both of the interwheelset structure and of the equivalent conicities of the wheelsets. It is shown that while parameters can be selected which provide static and dynamic stability and perfect steering for both directions of motion, there is a lightly damped mode of oscillation for any practical configuration and the significance of this is discussed.

## **SHIPS**

### 83-63

#### **Nonlinear Large-Amplitude Low-Frequency Ship Motions**

N. Salvesen

Div. of Engrg. and Weapons, Naval Academy, Annapolis, MD, Rept. No. USNA-EW-10-82, 30 pp (Apr 1982)

AD-A115 135

**Key Words:** Ships, Low frequencies, Wave forces, Time domain method

A new nonlinear time-domain method for predicting large amplitude motions for a ship advancing in a seaway has been developed. The seaway is represented by a second-order Stokes wave. A consistent nonlinear theory is derived by assuming that the frequency of encounter is small. Results obtained by computer codes show good agreement with

linear theory for small-amplitude waves, whereas large differences are found between the nonlinear method and linear theory for steeper waves.

### 83-64

#### **A Localized Finite-Element Method for Three Dimensional Ship Motion Problems**

K.J. Bai

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, Rept. No. DTNSRDC-82/042, 22 pp (May 1982)

AD-A115 643

**Key Words:** Ships, Finite element technique, Eigenvalue problems

An application of the localized finite-element method to a three-dimensional time-harmonic free surface flow in a canal is presented. Boundary conditions on both the free surface and the body are linearized and imposed on their equilibrium positions. By utilizing known set of eigenfunctions, the computation domain is reduced to a very small local domain where an eight-node linear three-dimensional element is used. Proper matching is also imposed between two sets of trial functions on the truncated boundary. To be solved are the problems concerning: six degree-of-freedom radiation and diffraction in three dimensions, two dimensional motion corresponding to the local flow at midship cross-sectional plane, and related eigenvalues. Specifically, two sets of results for two ship locations in a canal are presented.

## **AIRCRAFT**

(Also see Nos. 225, 233)

### 83-65

#### **Aircraft Sonic Boom: Studies on Aircraft Flight, Aircraft Design, and Measurement, 1964 - May, 1982 (Citations from the NTIS Data Base)**

NTIS, Springfield, VA, 227 pp (July 1982)

PB82-809948

**Key Words:** Aircraft noise, Sonic boom, Bibliographies

The reports discuss aerodynamic design of aircraft and wings, flight characteristics and maneuvers, supersonic transport characteristics, acoustic fields and noise measurement, government policies and regulations, meteorological parameters, shock waves, and supersonic and hypersonic wind tunnel tests, along with other theoretical and general investigations. Structural and biological effects are documented in separate published searches.

83-66

**Consideration of the Thickness in Calculating Non-Steady Subcritical Aerodynamic Forces (Prise en Compte des Effets d'Epaisseur dans le Calcul des Forces Aerodynamiques Instationnaires Subcritiques Application aux Interactions Fuselage-Surfaces Portantes)**

R. Barreau, M. Verdier, and J.P. Robert

Assn. Aeronautique et Astronautique de France, Paris, France, Rept. No. AAAF-NT-81-24, 49 pp (Nov 1981)

PB82-213554

(In French)

**Key Words:** Aerodynamic loads, Geometric effects, Aircraft

In this report, the effect due to the presence of the fuselage is introduced into a computer program previously developed for thin wings. This program is divided into four parts. First, a geometric lattice is determined upon the basis general data; next, coefficients of aerodynamic effect are calculated in form made discrete by a method of singularities; then, the matrix so obtained is inverted and solved; and last, the non-steady pressures and forces are calculated.

83-67

**The Lateral Response of an Airship to Turbulence**

J.J. Wroblewski, Jr.

Naval Postgraduate School, Monterey, CA, 151 pp (Dec 1981)

AD-A115 197

**Key Words:** Aircraft, Aerodynamic loads, Lateral response, Spectrum analysis

A method is derived for finding the linear response and loading transfer functions for the lateral aerodynamic case of airship flight through atmospheric turbulence. The functions obtained are in a form that can be applied to the various spectral analysis methods used to predict survivability currently employed by designers. A numerical example using the USS AKRON (ZR-4) is presented.

83-68

**A Two-Degree-of-Freedom Flutter Mount System with Low Damping for Testing Rigid Wings at Different Angles of Attack**

M.G. Farmer

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83302, 20 pp (Apr 1982) (Presented at VA Academy of Sci. Mtg., Blacksburg, VA, Apr 20-23, 1982)

N82-23549

**Key Words:** Aircraft wings, Flutter, Wind tunnel testing

A wind tunnel model mount system for conducting flutter research using a rigid wing was developed. The wing is attached to a splitter plate so that the two move as one rigid body. Wind tunnel data obtained by using the mount system are presented for a supercritical and a conventional airfoil. Both classical flutter and stall flutter data are presented.

83-69

**Transonic Flutter Study of a Wind-Tunnel Model of a Supercritical Wing with/without Winglet**

C.L. Ruhlín, F.J. Rauch, Jr., and C. Waters

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83279, 11 pp (Mar 1982) (Presented at 23rd AIAA/ASME/ASCE/AHS Struct., Sturctural Dyn. and Mater. Conf., New Orleans, May 10-12, 1982)

N82-23239

**Key Words:** Aircraft wings, Wind tunnel testing, Flutter

The model (a 1/6.5-size, semipan version of a wing proposed for an executive-jet-transport airplane) was tested with a normal wingtip, a wingtip with winglet, and a normal wingtip ballasted to simulate the winglet mass properties. Flutter and aerodynamic data were acquired at Mach numbers (M) from 0.6 to 0.95.

83-70

**Some Case Studies and the Significance of Fatigue Thresholds**

R.J.H. Wanhill

National Aerospace Lab., Amsterdam, The Netherlands, Rept. No. NLR-MP-81015-U, 15 pp (Apr 1981) (Presented at Intl. Symp. on Fatigue Thresholds, Stockholm, June 1981)

N82-23561

**Key Words:** Aircraft, Fatigue life

Examples of service failures, involving low-cycle and/or high-cycle fatigue, are described and discussed with respect to

the significance of thresholds for high-cycle fatigue crack propagation. The examples are: aircraft undercarriage cylinders made of high strength 4340 steel; aircraft gas turbine compressor drive shafts made of A286 steel; and aircraft gas turbine blades made of Rene 80 nickel-base superalloy.

83-71

**Commercial Jet Transport Crashworthiness**

E. Widmayer and O.B. Brende

Boeing Commercial Airplane Co., Seattle, WA, Rept. No. NASA-CR-165849, 255 pp (Apr 1982)  
N82-23207

**Key Words:** Crash research (aircraft), Crashworthiness

The results of a study to identify areas of research and approaches that may result in improved occupant survivability and crashworthiness of transport aircraft are given. The study defines areas of structural crashworthiness for transport aircraft which might form the basis for a research program. A 10-year research and development program to improve the structural impact resistance of general aviation and commercial jet transport aircraft is planned. As part of this program parallel studies were conducted to review the accident experience of commercial transport aircraft, assess the accident performance of structural components and the status of impact resistance technology, and recommend areas of research and development for that 10-year plan. The results of that study are also given.

83-72

**Theoretical and Experimental Investigation of the Dynamic Behavior of Parachute-Load Systems During Wind Tunnel Tests**

K.F. Doherr

Deutsche Forschungs- und Versuchsanstalt fuer Luftund Raumfahrt e.V., Brunswick, Germany, Rept. No. DFVLR-FB-81-29, 259 pp (July 30, 1981)  
N82-23202  
(In German)

**Key Words:** Air drop operations, Parachutes, Wind tunnel testing

Payload deceleration and stabilization by small parachutes was numerically treated. Aerodynamic force effects on various parachute models were studied in a wind tunnel, using a load measurement setup with four rotational degrees of freedom. Computerized simulation of observed oscillatory motions was undertaken. The system of nonlinear equations

of motion was solved. Simplified nonlinear and linearized cases with reduced degrees of freedom were approximated analytically.

## MISSILES AND SPACECRAFT

83-73

**On Modeling and Simulation of the Dynamics of Tether Connected Satellite Systems**

V.J. Modi, A.K. Misra, and D.M. Xu

Dept. of Mech. Engrg., The Univ. of British Columbia, Vancouver, BC, Canada V6T 1W5, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 217-219, 3 figs, 6 refs

**Key Words:** Satellites, Spacecraft, Lateral vibration, Flexural vibration

A general dynamical model for a system consisting of two satellites connected by a tether is presented. Three dimensional large rotational motion, longitudinal as well as transverse vibrations of the tether treated as a continuum, eccentricity of the orbit and aerodynamic drag in a rotating oblate atmosphere are taken into account. Equations of motion are obtained using a Lagrangian formulation.

## MECHANICAL COMPONENTS

### ABSORBERS AND ISOLATORS

(Also see No. 143)

83-74

**Active Control of Multistory Structures by Pole Assignment Method**

F. Amini

Ph.D. Thesis, Polytechnic Inst. of New York, 146 pp (1982)  
DA8217309

**Key Words:** Multistory buildings, Active control

The excitation of a structure due to dynamic loads can be controlled by using either passive or active mechanisms. This

dissertation is concerned with the active control method, utilizing the state feedback approach. The main purpose is to develop a technique to design and calculate the gain matrix by assigning the poles of the closed-loop dynamic system.

**83-75**

**The Similarity Methods for Seismic Qualification of Electrical Equipment**

D.T. Tang and A.J. Aycoob

Westinghouse Electric Corp., Pittsburgh, PA, ASME Paper No. 82-PVP-32

**Key Words:** Mountings, Equipment mounts, Seismic response, Dynamic tests

A simplified approach is proposed to examine the in-equipment seismic environments at component mounting levels for qualifying seismic capability of equipment assemblies. This approach, called the similarity method, employs the Rayleigh method for evaluating the degree of response similarity between benchmark qualified equipment and the equipment under investigation. The method is applied to a representative structure to illustrate the process for deriving similarity parameters.

**83-76**

**Seismic Snubber Modeling for Dynamic Analyses**

G.M. Hulbert and G.A. Schott

Westinghouse Electric Corp., Madison, PA, ASME Paper No. 82-PVP-48

**Key Words:** Snubbers, Mathematical models, Parameter identification technique, Seismic response

The importance of properly modeling the dynamic response of snubbers is discussed. This paper describes procedures to develop analytical snubber models for dynamic analyses. The development of analytical snubber models is also discussed along with techniques to determine the analytical snubber model parameters from snubber dynamic characterization test data. Of the techniques presented, the Bayesian parameter identification approach shows the greatest promise as a flexible method to determine parameters for complex models.

**83-77**

**Systems for Noise and Vibration Control**

W.E. Purcell

S/V, Sound Vib., 16 (8), pp 8, 10-12, 14-19 (Aug 1982) 16 figs

**Key Words:** Noise barriers, Acoustic absorption, Noise reduction, Vibration control, Reviews

Systems for noise and vibration control are finished products or components generally designed for specific purposes. These can be special custom-made items or off-the-shelf stock. They generally have laboratory or field tested performance ratings and catalog information will present the results. Most of these products combine the functions of sound absorption, sound barrier, and vibration damping and isolation into a single item. The degree to which each is incorporated depends on the use for which a specific product is intended. The principal function for which a product is designed determines its classification into one of four groups: sound absorptive systems, sound barrier systems, silencers, and vibration/shock control systems.

**83-78**

**Selection of Suspension Parameters for Stability of Wheelsets**

R.V. Dukkipati and R.R. Guntur

Div. of Mech. Engrg., Natl. Res. Council, Ottawa, Canada, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 157-158, 5 refs

**Key Words:** Suspension systems (vehicles), Wheelsets

A method has been proposed to facilitate the design of the longitudinal suspension of a wheelset. Using this method it is possible to draw stability boundaries on a parameter plane. It is shown that the results provided valuable insight into the problem of stability of a wheelset.

**83-79**

**Semi-Active Heave and Pitch Control for Ground Vehicles**

D.L. Margolis

Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, Vehicle Syst. Dynam., 11 (1), pp 31-42 (Feb 1982) 9 figs, 1 table, 6 refs

**Key Words:** Suspension systems (vehicles), Active vibration control, Semiactive isolation, Ground vehicles

A model is presented which includes both the heave and pitch motions of a vehicle traversing a roadway. Provision is made for testing totally passive, totally active, and semi-active secondary suspensions. Control strategies are developed for the totally active case and vehicle isolation is demonstrated. These active controllers are then modified to be semi-active; i.e., no power is provided from the controller to the vehicle. The semi-active isolation is shown to be comparable to the totally active system and much superior to the passive suspension.

## SPRINGS

83-80

### The Large Displacements and Dynamic Stability of Springs Using Helical Finite Elements

J.E. Mottershead

Lucas Research Ctr., Dog Kennel Ln., Shirley, Solihull, West Midlands, UK, Intl. J. Mech. Sci., 24 (9), pp 547-558 (1982) 12 figs, 1 table, 14 refs

**Key Words:** Helical springs, Dynamic stability

The differential equations of Wittrick are extended to allow large displacements of the helix and consistent geometric stiffness matrices are presented. An investigation of static and dynamic stability and nonlinear wave propagation is offered. The performance of the method is measured by comparison with previously published work.

## TIRES AND WHEELS

(Also see No. 78)

83-81

### Railway Wheel Squeal (1st Report, On Frequency of Squeal)

M. Nakai, Y. Chiba, and M. Yokoi

Faculty of Engrg., Kyoto Univ., Yoshida-honmachi, Sakyo-ku, Kyoto, Japan, Bull. JSME, 25 (205), pp 1127-1134 (July 1982) 11 figs, 4 tables, 4 refs

**Key Words:** Wheels, Railway wheels, Noise generation, Friction

An apparatus was made consisting of a steel rod and a thin disk and an actual wheel squeal was compared with the experimental one. Train squeal noise is generated in particular kinds of nodal diameter modes of axial vibration of the

wheel and at these frequencies the damping coefficient has little value. These characteristics have the same tendency as those of squeal noise generated in the fundamental experiment. An autonomous nonlinear differential equation for the frictional vibration of the disk was solved by the averaging method and the effects of the damping coefficients and contact load on the stability of the solutions was investigated.

83-82

### A Theory of Wheelset Forces for Two Point Contact Between Wheel and Rail

J. Piotrowski

Inst. of Vehicles, Warsaw Tech. Univ., Poland, Vehicle Syst. Dynam., 11 (2), pp 69-87 (Apr 1982) 12 figs, 1 table, 2 refs

**Key Words:** Wheelsets, Interaction: rail-wheel

This paper describes a quasistatic theory of wheelset forces for an important practical case of the wheelset rolling when one of the wheels touches the rail in two contact zones. One of these zones lies on the tread and the other on the wheel flange. For such contact the specific problem of finding the distribution of forces between the tread and flange arises. The simultaneous frictional rolling contact problems for both contact zones are described with Kalker's nonlinear theory and wheelset equilibrium equations. The numerical results presented are for an individual wheelset on straight track, the distribution of forces being described for a wide range of loading conditions. The influence of steering on the distribution of forces is also presented.

## BLADES

83-83

### A Shell Analysis of Turbine Blade Vibrations

K. Ravn-Jensen

The Technical Univ. of Denmark, Lyngby, Denmark, Intl. J. Mech. Sci., 24 (10), pp 581-587 (1982) 5 figs, 3 tables, 15 refs

**Key Words:** Blades, Turbine blades, Shells, Centrifugal forces, Free vibration

Free vibrations of turbine blades are analyzed numerically by means of a general shell theory. The effect of centrifugal force is taken into account, and it is found possible to examine a wide class of blades. The continuous shell problem

is discretized through a finite difference energy method, working on a simple rectangular grid mapped onto the blade surface by parameter functions. Three examples are shown.

**83-84**

**Unsteady Pressure on a Cambered Blade under Periodic Gust**

Y. Murakami, T. Hirose, and T. Adachi

Faculty of Engrg. Science, Osaka Univ., 1-1, Machikanayama-cho, Toyonaka, Osaka, 560 Japan, Bull. JSME, 25 (206), pp 1252-1257 (Aug 1982) 16 figs, 5 refs

**Key Words:** Blades, Wind-induced excitation, Periodic excitation

An analysis is given for determining the unsteady pressure on a cambered blade with angle of attack moving through both longitudinal and transverse gusts. The nondimensional unsteady pressure functions are defined for seven combinations of the effects of longitudinal and transverse gusts, angle of attack and camber. Based on these functions, examples of obtained results describing the unsteady pressure distribution on the blade are presented.

**83-85**

**Calculating the Characteristic Frequencies of Non-Massive Blades of Axial Vents (Berechnung der Eigenfrequenzen von hohlen Axialventilatorschaufeln)**

K. Bordas

Forsch. Ingenieurwesen, 48 (3), pp 87-95 (1982) 9 figs, 16 refs  
(In German)

**Key Words:** Blades, Natural frequencies

The characteristic frequencies of non-massive blades of axial vents are calculated using two-dimensional transfer matrices and obeying the laws of similarity in variations of size. This is varied for different blade designs.

**83-86**

**Experiments on Sound Radiation from Propeller Blades**

K. Verhulst and A. Debruijn

Technisch Physische Dienst TNO-TH, Delft, The Netherlands, Rept. No. TPD-908-725, TDCK-75537, 41 pp (Aug 17, 1981)

N82-24947

**Key Words:** Blades, Propeller blades, Sound waves, Wave propagation

The effect of blade damping and air bubbles on cavitation noise and radiation, and the damping effect of an antisinging edge are studied. Completely flat conical and aluminum blades are used. One conical blade had a viscoelastic sandwich layer. Cavitation is simulated by steam injection.

## BEARINGS

(See No. 88)

## GEARS

**83-87**

**Study on Bending Fatigue Strength of Bevel Gears (1st Report, Tooth Profile and Root Stresses of Straight Bevel Gears of Gleason Type)**

S. Oda, T. Koide, and Y. Okamura

Faculty of Engrg., Tottori Univ., 4-101 Minami, Koyama-cho, Tottori, Japan, Bull. JSME, 25 (205), pp 1173-1179 (July 1982) 14 figs, 2 tables, 9 refs

**Key Words:** Gears, Bevel gears, Gear teeth, Fatigue life

The characteristics of tooth profile of straight bevel gears of Gleason type are examined and the root stresses are investigated experimentally by making use of a static loading apparatus. It was found that the tooth profile of straight bevel gears of Gleason type deviates from spherical involute curve in both the tip and the root of the tooth and that the root stresses at the middle of tooth trace are larger than those at the toe and the heel.

**83-88**

**Dynamic Behavior of Straight Bevel Gear (3rd Report, On the Effect of Preloading on Bearing)**

Y. Terauchi, M. Fujii, and Y. Oubatake

Faculty of Engrg., Hiroshima Univ., Saijo-cho, Higashihiroshima, Japan, Bull. JSME, 25 (206), pp 1329-1335 (Aug 1982) 20 figs, 5 refs

**Key Words:** Gears, Bevel gears, Shafts, Bearings

By use of a preload detector, the initial preload of a bearing are determined. The change of preload, the dynamic load of gear tooth and the displacements of bevel gear in three directions are measured under a constant torque and the results are discussed.

## CABLES

(Also see No. 227)

**83-89**

### Spur Gears Meshing Action Simulated by Computer

H. Yelle, R. Gauvin, and D.J. Burns

Département de génie mécanique, Ecole Polytechnique de Montréal, Montréal, Québec, Canada, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 195-197, 4 figs, 8 refs

**Key Words:** Gears, Fatigue life, Computer-aided techniques

This paper describes the analogy used by a computer program that simulates the meshing action that takes place when two spur gears are run together. The program finds the first and last points of contact between two teeth and calculates root bending stresses at several positions of the point of contact along the line of action. The program can perform calculations for gear pairs of dissimilar materials and allows the designer to vary several gear geometry and operating parameters.

## FASTENERS

**83-90**

### Finite Element Analysis of Advanced Composite Structures Containing Mechanically Fastened Joints

E. Baumann

Rockwell Intl. Corp., Tulsa Div., P.O. Box 51308, Tulsa, OK 74151, Nucl. Engrg. Des., 70 (1), pp 67-83 (June 1982) 23 figs, 5 tables, 20 refs

**Key Words:** Fasteners, Joints (junctions), Composite structures, Finite element technique

Although the usual engineering practice is to ignore joint effects in finite element models of overall structures, there are times when the inclusion of fastener effects in a model

is necessary for accurate analysis. This paper describes some simple but accurate methods for accommodating this modeling requirement. The approach involves correlation of test results from a few composite mechanically fastened joints with finite element analyses of joints. Some emphasis is given to the importance of properly reducing test data in order to obtain meaningful correlations with finite element analysis.

## VALVES

**83-91**

### Dynamic Qualification Test Procedure for BWR Valves

D. Bhargava, N.A. Muni, A.W. Chan, and S.M. Feldman

Stone & Webster Engrg. Corp., Cherry Hill, NJ, ASME Paper No. 82-PVP-33

**Key Words:** Valves, Piping systems, Nuclear reactor components, Dynamic tests

This paper presents a generic dynamic qualification procedure consisting of uniaxial, single frequency tests to qualify a valve assembly mounted in a BWR nuclear power plant piping system which is subjected to suppression pool hydrodynamic loads. The procedure developed is preferable to the conventional required response spectrum loading approach.

## STRUCTURAL COMPONENTS

### STRINGS AND ROPES

**83-92**

### Simple Inequalities in the Vibrating String and Heat Conduction Problems

M. Pachter and R.I. Becker

Natl. Res. Inst. for Math. Sci., Pretoria, South Africa, Rept. No. CSIR-T-WISK-211, 26 pp (July 1981) N82-22940

**Key Words:** Strings

Certain inequalities are presented, related to the  $L(2)$  norms of the solutions to the vibrating string and heat conduction

partial differential particular, an L(2) maximum principle is derived for the heat equation, and similar inequalities for the vibrating string problem.

**83-93**

**Validation of Computer Models of Cable System Dynamics**

D.B. Dillon

EG and G Washington Analytical Services Ctr., Inc.,  
Rockville, MD, Rept. No. NCEL-CR-82.015, 191 pp  
(Apr 1982)  
AD-A114 957

**Key Words:** Cables, Moorings, Computer programs, Experimental test data

Comparisons are made between measurements taken during four series of dynamic cable experiments and simulations of the experimental events using two computer models, SEADYN and SNAP-LOAD.

**83-94**

**Test Cases for SEADYN Verification**

P.E. Nordstrom and H. Ottsen

Western Instruments Corp., Oxnard, CA, Rept. No.  
NCEL-CR-82.014, 249 pp (Apr 1982)  
AD-A114 978

**Key Words:** Computer programs, Cables, Moorings

This report includes actual input decks and associated outputs for demonstration of the SEADYN cable dynamics computer model. The input problems are intended to allow for the verification of the model if it is transferred for operation on non-CDC computers.

**83-95**

**Non-Linear Analysis and Simulations of Auto-Oscillations of Twin Bundle**

A.R.E. Oliveira and W.M. Mansour

Dept. of Mech. Engrg., Fed. Univ. of Rio de Janeiro,  
Brazil, System Simulation and Scientific Computation,  
Proc. of the 10th IMACS World Congress,  
Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 58-60,  
2 figs, 9 refs

**Key Words:** Cables, Transmission lines, Wind-induced excitation, Self-excited vibrations

The lift and drag coefficients of a conductor in the wake of another fixed one are represented by simple functions using published experimental data. The motion is simulated by a two-degrees of freedom nonlinear coupled model. Non-linear analysis using the Krylov and Bogolyubov asymptotic approach revealed the existence of limit cycles and zones for stable auto-oscillations.

**83-96**

**Current Methods for Analyzing Dynamic Cable Response 1979 to the Present**

H. Migliore and R.L. Webster

Portland State Univ., Portland, OR 97207, Shock  
Vib. Dig., 14 (9), pp 19-24 (Sept 1982) 34 refs

**Key Words:** Cables, Submerged structures, Finite element technique, Method of weighted residuals, Reviews

Developments since 1979 are outlined. Emphasis is on ocean engineering applications and closely related activities. Two general computer-oriented approaches have become predominant: the finite element method and the method of weighted residuals.

**83-97**

**A Compendium of Tension Member Properties for Input to Cable Structure Analysis Programs**

J.F. Wadsworth, III

Western Instruments Corp., Oxnard, CA, Rept. No.  
NCEL-CR-82.017, 70 pp (Apr 1982)  
AD-A115 019

**Key Words:** Cables, Mechanical properties, Computerized simulation

This report is a collection and condensation of cable properties used in computer simulations of cable dynamics problems. Data were taken from a variety of sources, and include weight per foot (in air and immersed), elastic modulus, breaking strength, cross-sectional area, and drag and added mass coefficients. Cable types include chain, wire rope, synthetic and electromechanical.

**83-98**

**SEADYN Mathematical Models**

R.L. Webster

Brigham City, UT, Rept. No. NCEL-CR-82.019, 63 pp (Apr 1982)  
AD-A114 994

**Key Words:** Cables, Trusses, Moorings, Computer programs

This manual presents the theoretical background material for the SEADYN cable, truss, and mooring program. SEADYN uses the finite element method for modeling the cables, trusses, and mooring lines. Two elements are treated: the one-dimensional Simplex (truss) element and a bottom-limited catenary. Lumped parameter concepts are used in treating buoys, anchors, floats, etc. Rigid body models are used for ships, platforms, mooring buoys, etc. A cartesian 3-D geometric space is used throughout.

**83-99**

**Flow-Induced Oscillations of OTEC Mooring and Anchoring Cables: State of the Art**

O.M. Griffin

Naval Res. Lab., Washington, DC, Rept. No. NRL-MR-4766, 88 pp (May 27, 1982)  
AD-A115 462

**Key Words:** Cables, Moorings, Fluid-induced excitation

The objective of this report is to present an overview of the state of knowledge concerned with marine cable strumming oscillations and to apply these findings of the development of design methods for deep ocean cable systems. The report emphasizes recent findings that are relevant to the design of OTEC power plant mooring and riser cable systems.

## BARS AND RODS

**83-100**

**Numerical and Experimental Investigations of the Pulse Wave Response of a Necked Rod**

M. Zindeluk

Dept. of Mech. Engrg., Fed. Univ. of Rio de Janeiro, COPPE/UFRJ, Brazil, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 157-159, 3 figs, 9 refs

**Key Words:** Wave propagation, Bars, Variable cross section, Rods

A numerical procedure for the solution of a type of bidimensional second kind Volterra integral equation with continuous or piecewise continuous kernels, is outlined. This equation appears as a means of building the Riemann and Green functions for one-dimensional wave propagation in non-homogeneous media with smoothly and sectionally smoothly varying parameters. This is exemplified for the simplest case of a bar with varying cross-sectional area. Numerical and experimental results are presented for the first case tested in the ongoing research and some comments are drawn on the difficulties associated with identification of the variable parameter profile.

**83-101**

**In-Plane Vibrations of Curved Bars with Varying Cross-section**

K. Suzuki and S. Takahashi

Faculty of Engrg., Yamagata Univ., Yonezawa, Japan, Bull. JSME, 25 (205), pp 1100-1107 (July 1982)  
11 figs, 12 refs

**Key Words:** Bars, Curved rods, Variable cross section, Natural frequencies, Mode shapes

The in-plane vibrations of a curved bar with varying cross-section are analyzed using the classical theory. The equations of vibration are solved exactly by a series solution. As numerical examples, the natural frequencies and mode shapes of symmetric elliptic arc bars with both ends clamped and simply supported are obtained. Variations of the natural frequencies and mode shapes of the cross-section are clarified.

**83-102**

**Vibrations of Cylindrical Shells with Varying Thickness**

K. Suzuki, E. Anzai, and S. Takahashi

Faculty of Engrg., Yamagata Univ., Yonezawa, Japan, Bull. JSME, 25 (205), pp 1108-1119 (July 1982) 17 figs, 14 refs

**Key Words:** Shells, Cylindrical shells, Variable cross section, Natural frequencies, Mode shapes

Free vibrations of a cylindrical shell, symmetric about the cross-section at the center and of varying thickness quadratically, are analyzed by both the classical theory and an improved one. The equations of vibration are solved exactly by a series solution and three boundary conditions are considered: both ends clamped, simply-supported, and free. The

effects of the variations of thickness, upon the natural frequencies and mode shapes are clarified.

## BEAMS

(Also see No. 155)

83-103

### Response of Yielding MDF Structures to Stochastic Excitation

T.-S. Jan

Ph.D. Thesis, Rice Univ., 196 pp (1982)

DA8216324

**Key Words:** Beams, Buildings, Multidegree of freedom systems, Random response, Stochastic processes

The random response of bilinear hysteretic yielding systems subjected to a stationary Gaussian white noise excitation is studied. The responses considered are the root mean square interfloor displacements of yielding multi-degree-of-freedom shear beam type building structures. Simulation results are presented as well as analytical methods to approximate the response levels. Both stationary response levels and the transient build-up of response for systems which are initially at rest are investigated. Nearly elastoplastic 2DF, 4DF and 10DF systems are studied with different stiffness distribution over the height (uniform or tapered) and with different damping ratios.

83-104

### Investigation of the Effect of Impact Loading on Concrete Beams

G. Hughes and A.W. Beeby

Des. Res. Dept., Cement & Concrete Assn., UK, Struc. Engr., 60B (3), pp 45-52 (Sept 1982) 16 figs, 6 refs

**Key Words:** Beams, Concretes, Impact response

Eighty pin-ended and 12 simply supported beams were tested by dropping a nominally rigid striker onto the beam at midspan. For each test the impact force history and the beam displacements (maximum and residual) were measured. The simple beam vibration model, which allows for strain energy of bending and transverse inertia, is shown to be applicable over the test ranges. The problem is amenable to parametric representation, and the importance of two parameters, the mass ratio and the pulse ratio, is recognized.

83-105

### Nonlinear Analysis of Beams. Part II: Finite Element Methods

M. Sathymoorthy

Dept. of Mech. and Industrial Engrg., Clarkson College of Tech., Potsdam, NY 13676, Shock Vib. Dig., 14 (9), pp 7-18 (Sept 1982) 176 refs

**Key Words:** Beams, Nonlinear theories, Finite element technique, Reviews

In Part I, classical methods of analysis for nonlinear beam problems were reviewed. In recent years, finite element methods have often been used for nonlinear static and dynamic analysis of beams and beam-type structures. Part II is a review of such literature. The search attempts to cover all the publications from the earliest research in this area.

83-106

### Elastic Analysis of Beam Support Impact

M.A. Salmon, V.K. Verma, and T.G. Youtsos

Sargent & Lundy Engineers, Chicago, IL, ASME Paper No. 82-PVP-58

**Key Words:** Beams, Springs, Piping systems, Supports, Nuclear reactor components, Computer programs, Seismic response, Bernoulli-Euler method, Modal analysis

The effect of gaps present in the seismic supports of nuclear piping systems has been studied with the use of such large general purpose analysis codes as ANSYS. Exact analytical solutions to two simple beam impact problems are obtained to serve as benchmarks for the evaluation of the ability of such codes to model impact between beam elements and their supports. Bernoulli-Euler beam theory and modal analysis are used to obtain analytical solutions for the motion of simply supported and fixed ended beams after impact with a spring support at midspan.

## COLUMNS

83-107

### Shear Strength and Deterioration of Short Reinforced Concrete Columns under Cyclic Deformations

H. Umehara

Ph.D. Thesis, Univ. of Texas at Austin, 276 pp (1982) DA8217946

**Key Words:** Columns, Reinforced concrete, Cyclic loading, Seismic excitation

A series of ten short columns with rectangular sections (9 x 16 in.) were tested in this study and compared with the results of square columns (12 x 12 in.). Loading history and level of axial load were the main variables. It was concluded that the maximum capacities of the columns with diagonal unidirectional loading could be estimated by an interaction line (circle or ellipse) connecting the maximum capacities of the column under unidirectional loading along the principal axis.

## FRAMES AND ARCHES

**83-108**

### **Optimal Design of Seismic-Resistant Planar Steel Frames**

R.J. Balling, V. Ciampi, K.S. Pister, and E. Polak  
Earthquake Engrg. Res. Ctr., Univ. of California,  
Berkeley, CA, Rept. No. UCB/EERC-81/20, NSF/  
CEE-81049, 127 pp (Dec 1981)  
PB82-220179

**Key Words:** Frames, Steel, Seismic design

This report presents a method for the seismic-resistant design of planar rectangular braced or unbraced steel frames. An important feature of the method is that nonlinear step-by-step integration is used as the analysis technique within the design process itself. The frame design method is illustrated by application to a nontrivial example 4-story 3-bay moment-resisting steel frame. The practicality and reliability of the method for this example problem are assessed.

**83-109**

### **Shape Optimization of Trusses Subject to Strength, Displacement, and Frequency Constraints**

J.E. Felix  
Naval Postgraduate School, Monterey, CA, 73 pp  
(Dec 1981)  
AD-A114 450

**Key Words:** Trusses, Optimization, Numerical analysis, Frequency constraints

Three-dimensional trusses are designed for minimum weight, subject to constraints on: member stresses, Euler buckling,

joint displacements and system natural frequencies. Multiple static load conditions are considered. The finite element displacement method of analysis is used and eigenvalues are calculated using the subspace iteration technique. All gradient information is calculated analytically.

**83-110**

### **Seismic Analysis of Free-Standing Fuel Racks**

C.B. Gilmore  
Westinghouse Electric Corp., Pittsburgh, PA, ASME  
Paper No. 82-PVP-17

**Key Words:** Racks, Fuel tanks, Seismic response, Modal damping

A nonlinear transient dynamic time-history analysis of freestanding spent fuel storage racks subjected to seismic excitation is presented. Acceleration time history excitation development is discussed. Modeling considerations, such as the initial status of nonlinear elements, number of mode shapes to include in the analysis, modal damping, and integration time-step size are presented.

## PANELS

**83-111**

### **Analysis of Fatigue Cracks in Center Cracked Panels and Cold-Worked Fastener Holes**

M. Nakagaki and S.N. Atluri  
Naval Res. Labs., Washington, DC, ASME Paper No.  
82-PVP-24

**Key Words:** Panels, Hole-containing media, Fatigue life, Finite element technique

Presented is a quasi-static elastic-plastic finite element analysis of fatigue growth of cracks in center cracked panels and near cold-worked fastener holes. In this analysis, singular finite elements, within which are embedded the HRR singularities for strains/stresses, are used.

## PLATES

**83-112**

### **Solution of Transient Plate Bending Problems by Boundary Integral Equations (Étude des mouvements**

**transitoires de flexion d'une plaque par la méthode des équations intégrales de frontière)**

G. Bezine and D. Gamby

Laboratoire de Mécanique des Solides, E.R.A. no. 218, Université de Poitiers, 40, avenue de Recteur-Pineau, 86022 Poitiers, J. de Mécanique, 1 (3), pp 451-466 (1982) 4 figs, 12 refs  
(In French)

**Key Words:** Plates, Flexural vibration

A reciprocity theorem is established relating two solutions of the differential equations which describes the motion according to Kirchhoff's theory. By using an appropriate fundamental solution an integral representation for deflection and its normal derivative along the edge is obtained, valid for any boundary problem.

**83-113**

**Vibrations of Nonhomogeneous Plates of Variable Thickness**

J.S. Tomar, D.C. Gupta, and N.C. Jain

Univ. of Roorkee, Roorkee, India, J. Acoust. Soc. Amer., 72 (3), pp 851-855 (Sept 1982) 4 figs, 6 refs

**Key Words:** Plates, Variable cross section, Free vibration

A simple model is presented for use by research workers in engineering design and technology where the investigations are devoted to the nonhomogeneous elastic bodies of variable thickness. The nonhomogeneity in materials arises due to imperfections in the material and therefore in nonhomogeneous elastic bodies the material properties are not constant but vary with the position in a random manner. Plywood, timber, delta wood, or fiber reinforced plastics are some examples.

**83-114**

**Acoustic Radiation from Fluid-Loaded Elastic Plates. II. Symmetric Modes**

B.L. Woolley

Naval Ocean Systems Ctr., San Diego, CA 92152, J. Acoust. Soc. Amer., 72 (3), pp 859-869 (Sept 1982) 7 figs, 12 refs

**Key Words:** Plates, Elastic properties, Fluid-induced excitation, Elastic waves, Sound waves, Wave propagation

A mathematical method for extending equations of motion to include higher order symmetric modes is presented and discussed. This method is illustrated by the development of equations of motion for the first two and the first three symmetric modes of plate vibration. The form of the Lyamshév plate equation of motion is used as a starting point for the development of the new equations. Transmission through an infinite elastic plate is calculated for developed plate equations of motion incorporating four antisymmetric and three symmetric modes of plate vibration.

**83-115**

**Vibration and Buckling and Circular Plates of Variable Thickness**

B. Valerga de Greco and P.A.A. Laura

Inst. of Appl. Mech., 8111-Puerto Belgrano Naval Base, Argentina, J. Acoust. Soc. Amer., 72 (3), pp 856-858 (Sept 1982) 4 figs, 3 tables, 6 refs

**Key Words:** Plates, Circular plates, Variable cross section, Flexural vibrations, Ritz method

The Ritz method and polynomial coordinate functions are used to obtain an approximate yet quite accurate and simple solution to the title problem. Results of frequency and buckling coefficients are obtained as a function of several combinations of the governing mechanical parameters.

**83-116**

**Dynamic Stability of Orthotropic Annular Plates under Pulsating Radial Loads**

J. Tani and H. Doki

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Acoust. Soc. Amer., 72 (3), pp 845-850 (Sept 1982) 6 figs, 1 table, 7 refs

**Key Words:** Plates, Annular plates, Orthotropism, Parametric resonance, Pulse excitation

The effect of the polar orthotropic material property on the parametric resonance of clamped annular plates is investigated theoretically. The pulsating radial forces with the same period act along both the inner and outer edges of the plate. The problem is reduced to that of a finite degree-of-freedom system with the Galerkin procedure, the stability of which is examined by using Hurwitz's method. The instability regions of both principal and combination resonances are determined for a wide range of exciting frequencies with the effect of the static uniform compression taken into consideration. It is found, among others, that the wavenumber

dependence of the dynamic stability is changed remarkably by the variation in the polar orthotropic material property.

**83-117**

**Computational Aspects of Eigenproblems of Large Structural Systems Using a Nested Dissection Numbering Scheme and Subspace Iteration Method**

T.-C. Cheu

Ph.D. Thesis, Univ. of Texas at Austin, 244 pp (1982)  
DA8217835

**Key Words:** Eigenvalue problems, Plates, Substructuring methods, Finite element technique

Computer algorithms for static analysis and for eigenproblems of large structures are developed. Eigenproblems of simply supported plates divided into large number of finite elements are used as examples to illustrate the efficiencies of the algorithms developed. A substructuring technique is used to reduce the size of eigenproblems and to obtain approximate eigenpairs. These approximate solutions are then used to retrieve the starting iteration vectors for subspace iterations.

**SHELLS**

(Also see Nos. 26, 210)

**83-118**

**Response of Containment Vessels to Explosive Blast Loading**

T.A. Duffey, R.R. Karpp, and R.T. Neal

Univ. of New Mexico, Albuquerque, NM, ASME Paper No. 82-PVP-64

**Key Words:** Containment structures, Shells, Blast response

The response of steel containment vessels to the blast loading produced by the detonation of high explosives is investigated by experiments, computations, and analysis. The vessels are thin-walled shell structures that are nearly spherical. All explosive charges are solid spheres, centrally initiated and centrally positioned within the vessels. Most of the work concerns vessels that contain, in addition to the explosive charge, air at ambient or reduced pressures.

**83-119**

**Vibrational Characteristics and Seismic Analysis of Cylindrical Liquid Storage Tanks**

J.W. Tedesco

Ph.D. Thesis, Lehigh Univ., 230 pp (1982)  
DA8218697

**Key Words:** Shells, Cylindrical shells, Storage tanks, Seismic analysis, Fluid-filled containers, Natural frequencies, Fundamental frequency, Mode shapes

This dissertation presents the results of an in-depth investigation concerning the vibrational characteristics and seismic analysis of ground supported, circular cylindrical liquid storage tanks subject to a horizontal component of earthquake ground motion. The scope of the study includes empty, partially full, and completely full tanks. Simple analytical expressions, in the form of cubic polynomials, are developed for empty tanks which accurately predict frequencies and radial mode shapes corresponding to the fundamental mode of vibration. These expressions form the basis of simplified procedures for determining shell stresses and displacements, base shears, and overturning moments induced in empty cylindrical tanks by earthquake ground motion. The effects of a roof structure and support conditions upon the vibrational characteristics of cylindrical tanks are also examined.

**83-120**

**Seismic Response of the Flexible Fluid-Tank Systems - A Numerical Study**

D.C. Ma, R.W. Seidensticker, Y.W. Chang, and W.K. Liu

Argonne Natl. Lab., Argonne, IL, ASME Paper No. 82-PVP-6

**Key Words:** Fluid-filled containers, Storage tanks, Seismic response

Current practice in the seismic design of liquid storage tanks is reviewed. Significant numbers of failures in tanks designed under past practices suggest the need to examine more closely the assumptions made in the design and the resulting predicted behavior versus the actual, observed behavior. A coupled fluid-structure finite element method is presented for the seismic analysis of flexible fluid-tank systems. A detailed parametric study is then developed. It is found that the hydrodynamic forces in flexible tanks may be substantially greater than those predicted when the tank walls are assumed to behave as rigid bodies.

**83-121**

**Dynamic Characteristics of Liquid Storage Tanks**

M.A. Haroun and G.W. Housner

Civil Engrg. Dept., Univ. of California, Irvine, CA 92717, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 783-800 (Oct 1982) 9 figs, 3 tables, 11 refs

**Key Words:** Storage tanks, Cylindrical shells, Natural frequencies, Mode shapes, Sloshing, Fluid-filled containers

A reliable and computationally effective method for calculating the dynamic characteristics of ground-supported cylindrical tanks is developed. The method offers a rigorous treatment of the interaction problem and provides a starting point for the consideration of the complicating factors which influence the dynamic behavior of tanks. The liquid region is treated analytically and only the shell is modeled by finite elements. The reliability of the analysis is illustrated by computing modes and natural frequencies of full-scale tanks and comparing them with the results of vibration tests.

### 83-122

#### **Complications in Free Vibration Analysis of Tanks**

M.A. Haroun and G.W. Housner

Civil Engrg. Dept., Univ. of California, Irvine, CA 92717, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 801-818 (Oct 1982) 9 figs, 7 tables, 10 refs

**Key Words:** Tanks (containers), Storage tanks, Cylindrical shells, Sloshing, Fluid-filled containers

A simple and computationally effective method for computing the dynamic characteristics of ground-supported, cylindrical liquid storage tanks is developed. A generalization of this method is presented herein to include some complicating factors which affect these characteristics. The validity of the method of analysis has been confirmed by both scale model testing and field measurements of the vibrational characteristics of full-scale tanks.

### 83-123

#### **Failure of Liquid Storage Tanks Due to Earthquake Excitation**

C.-F. Shih

Earthquake Engrg. Res. Lab., California Inst. of Tech., Pasadena, CA, Rept. No. EERL-81-04, NSF/CEE-81095, 215 pp (1981)  
PB82-215013

**Key Words:** Storage tanks, Fluid-filled containers, Earthquake damage, Seismic design

The damage suffered by above-ground, liquid storage tanks during earthquakes is reviewed, and the forced vibration, failure criterion, and appropriate design procedures of those tanks under seismic excitation are examined. This is done using scale model testing coupled with simplified analysis procedures. Complete dynamic characterization of the structure and fluid/structure combination is carried out, allowing for the identification of the response and failure modes as well as the significance of tank parameters on these models.

## **PIPES AND TUBES**

(Also see Nos. 91, 106, 147)

### 83-124

#### **On Matrix Parameters of Acoustic Elements and Their Applications to the Acoustic Simulation of Piping Systems**

C.W.S. To and A.G. Doige

Dept. of Mech. Engrg., Univ. of Calgary, Calgary, Alberta, Canada T2N 1N4, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 171-173, 2 figs, 22 refs

**Key Words:** Piping systems, Acoustic pulses, Computer programs

Various formulations for matrix parameters of acoustic elements are examined and a computer program for gas pulsation analysis and the acoustic simulation of piping systems is developed. The philosophy behind the development is described and several examples are analyzed.

### 83-125

#### **The Response of a Piping System to High Frequency Excitation**

T.G. Youtsos, D. Collins, M.A. Salmon, and V.K. Verman

Public Power Corp., Athens, Greece, ASME Paper No. 82-PVP-57

**Key Words:** Piping systems, Nuclear reactor components, Seismic response, High frequency excitation

The response of nuclear piping systems in the range above 33 Hz has been neglected in the past. Pool dynamic loads in BWR plants have significant content at frequencies much

higher than 33 Hz. In this paper an assessment is made of the impact of this high frequency excitation on the combined response to simultaneous seismic and pool dynamic loading.

**83-126**

**A Procedure to Incorporate Effects of Seismic Events in a Quasi-Static Piping System Inelastic Analysis**

D.F. Rotoloni and A.K. Dhalla  
Swanson Engrg. Assoc. Corp., McMurray, PA, ASME  
Paper No. 82-PVP-28

**Key Words:** Piping systems, Nuclear reactors, Seismic response

Inelastic analysis of a prototypic liquid metal fast breeder reactor piping system is generally performed without explicit consideration of time-dependent seismic loading. This paper presents an approximate procedure to simulate dynamic seismic loading as an equivalent static load for inelastic analysis. This procedure uses the results of the available linear seismic response spectrum analysis to calculate external (statistically equivalent) loads.

**83-127**

**A Probabilistic Comparative Study of Response Spectrum Techniques**

O. Kustu, D.P. Jhaveri, and J.A. Blume  
URS/John A. Blume & Assoc., San Francisco, CA,  
ASME Paper No. 82-PVP-49

**Key Words:** Piping systems, Nuclear reactor components, Response spectra

The findings of a study that investigated, on a probabilistic basis, the relative conservatisms represented by the various intra- and intermodel combination methods used in response spectrum analysis of nuclear piping systems, are summarized.

**83-128**

**Avoiding Tap Line Vibration Failures**

D.E. Olson and H.S. Chun  
Sargent & Lundy Engineers, Chicago, IL, ASME  
Paper No. 82-PVP-54

**Key Words:** Pipes (tubes), Vibration control

Tap line routing and support techniques that minimize failures and additionally result in a decreased analysis and

installation effort are discussed. Various typical designs are illustrated. These designs mitigate the effects of operational vibrations and also enable the majority of tap lines to be qualified via a generic stress analysis.

**83-129**

**Statistical Analysis of Crack Initiation and Fatigue Fracture of Thin-Walled Tubes Using the Weibull Law (Analyse de la fissuration et de la fiabilité de tubes à parois minces en fatigue avec la loi de Weibull)**

M. Bertrand, D. Lefebvre, and F. Ellyin  
SNIAS, Division des systemes ballistiques et spaciaux,  
B.P. no. 2, 78130 Les Mureaux, France, J. de Mecanique, 1 (3), pp 493-510 (1982) 5 figs, 4 tables, 21 refs  
(In French)

**Key Words:** Tubes, Steel, Fatigue life, Crack propagation, Statistical analysis

The Weibull-three-parameters-distribution function is used to analyze the damage and fracture in biaxial fatigue of thin-walled tubes of AISI 4340 steel subjected to a given strain ratio and amplitude. A new method is proposed for the estimation of the three parameters of the distribution function without prior assumptions. This method is based on minimizing the sum of quadratic errors between the observed and estimated values of the model, by using a nonlinear optimization program. The validity of the obtained distribution function is then verified.

**83-130**

**Dynamic Behavior of Ground for Seismic Analysis of Lifeline Systems**

T. Sato and A.D. Kiureghian  
Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UCB/EERC-82/01, NSF/CEE-82010, 78 pp (Jan 1982)  
PB82-218926

**Key Words:** Life line systems, Layered materials, Natural frequencies, Mode shapes, Seismic response

A new mathematical formula is derived for the general wave transfer function in multi-layered media with inhomogeneous and nonlinear properties of soil.

## DUCTS

83-131

### **Nonlinear Theory of Shocked Sound Propagation in a Nearly Choked Duct Flow**

M.K. Myers and A.J. Callegari

George Washington Univ., Washington, DC, Rept. No. NASA-CR-3549, 70 pp (Apr 1982)  
N82-24941

**Key Words:** Ducts, Sound propagation

The development of shocks in the sound field propagating through a nearly choked duct flow is analyzed by extending a quasi-one dimensional theory. The theory is applied to the case in which sound is introduced into the flow by an acoustic source located in the vicinity of a near-sonic throat. Analytical solutions for the field are obtained which illustrate the essential features of the nonlinear interaction between sound and flow. Numerical results are presented covering ranges of variation of source strength, throat Mach number, and frequency.

83-132

### **Sound Transmission through Ducts and Aircraft Noise Prediction. Volume 1. Technical Report**

J.J. Schauer, J.T. Datko, and R.W. Guyton

School of Engrg., Dayton Univ., OH, Rept. No. UDR-TR-81-118, AFWAL-TR-81-2131-VOL-1, 55 pp (Jan 1982)  
AD-A115 783

**Key Words:** Ducts, Acoustic linings, Aircraft noise, Noise prediction

Aircraft engine acoustical lining impedance models, ray acoustics, hydrodynamic modes, and transient analysis of sound propagation in variable area duct studies were applied to aircraft noise prediction. The effects of several duct lining configurations were predicted. The prediction was based on a model corrected to fit flight noise data and modified by including theoretical duct noise attenuation predictions.

83-133

### **Sound Propagation through a Variable Area Duct: Experiment and Theory**

R.J. Silcox and H.C. Lester

NASA Langley Res. Ctr., Hampton, VA, AIAA J., 20 (10), pp 1377-1384 (Oct 1982) 9 figs, 2 tables, 14 refs

**Key Words:** Ducts, Variable cross section, Sound propagation

A comparison of experiment and theory has been made for the propagation of sound through a variable area axisymmetric duct with zero mean flow. Measurement of the acoustic pressure field on both sides of the constricted test section was resolved on a modal basis for various spinning mode sources. Transmitted and reflected modal amplitudes and phase angles were compared with finite-element computations.

## BUILDING COMPONENTS

83-134

### **Sound Transmission through Windows I. Single and Double Glazing**

J.D. Quirt

Div. of Bldg. Res., Natl. Res. Council of Canada, Montreal Rd., Bldg. M-27, Ottawa, Ontario, Canada K1A 0R6, J. Acoust. Soc. Amer., 72 (3), pp 834-844 (Sept 1982) 20 figs, 24 refs

**Key Words:** Windows, Sound transmission, Experimental test data

The results of an extensive series of laboratory measurements of sound transmission through windows are presented. By reference to these data, the systematic dependence of the sound transmission loss on glass thickness and interpane spacing is evaluated.

83-135

### **Dynamic Centrifuge Testing of Cantilever Retaining Walls**

L.A. Ortiz

Ph.D. Thesis, California Inst. of Tech., 359 pp (1982)  
DA8218849

**Key Words:** Walls, Retaining walls, Earthquake damage, Centrifugal forces, Dynamic tests

An investigation was made into the behavior of flexible cantilever walls retaining a cohesionless soil backfill and

subjected to earthquake-type dynamic excitations using the centrifuge modeling technique. The study was motivated by the abundant observations of earth retaining structure damage and failures documented in earthquake damage reports. From the test data some empirical curves for relating the upper bound responses of the retaining walls to the strong motion characteristics of the applied earthquakes were obtained.

## ELECTRIC COMPONENTS

### GENERATORS

83-136

#### Airblast Damage to 30-kW, Skid-Mounted, Mobile Army Diesel Generator Sets

R.H. Femenias, W. Schuman, R. Warner, R. Peterson, and G. Teel

Harry Diamond Labs., Adelphi, MD, Rept. No. HDL-SR-82-1, 38 pp (Mar 1982)

AD-A114 817

**Key Words:** Generators, Hardened installations, Dynamic tests

A 30-kW, skid-mounted electric generator set of the tactical Army type was tested for structure-only damage under the impact of airblasts with peak pressures of 9.3 and 3.5 psi. Conclusions based on test results apply to three tactical models of 30-kW, skid-mounted, diesel generator sets available for Army field use. Test results indicate that generator sets will operate without interruption when exposed to an airblast with a peak pressure of 3.5 psi.

## DYNAMIC ENVIRONMENT

### ACOUSTIC EXCITATION

(Also see Nos. 77, 233)

83-137

#### Consistency Tests of Acoustic Propagation Models

F.B. Jensen and W.A. Kuperman

SACLANT ASW Research Centre, La Spezia, Italy, Rept. No. SACLANTCEN-MR-SM-157, 35 pp (Mar 1, 1982)

AD-A115 666

**Key Words:** Sound propagation

Three wave-theory models and one ray model are applied to four different ocean environments: a range-dependent surface duct, a deep-water environment with a homogeneous bottom, a shallow-water environment with a homogeneous bottom, and a sloping-bottom environment with a layered bottom. The consistency among the acoustic models is clearly demonstrated through the agreement between model results for the various test problems.

83-138

#### Nonlinear Acoustics. 1966 - May, 1982 (Citations from the NTIS Data Base)

NTIS, Springfield, VA, 172 pp (June 1982)

PB82-809344

**Key Words:** Sound transmission, Bibliographies

The bibliography cites reports relating to nonlinear acoustic theory, and applications to sound transmission in the atmosphere, oceans, solids, liquids, and gases. Nonlinear relationships are included for shock tubes, sonar equipment, sonic booms, acoustic deflectors, sound generators, acoustic delay lines, porous materials, pipes, ducts, and jet engine noise.

83-139

#### Acoustic Surface Wave Pulses and the Ringing of Resonances

H. Uberall, G.C. Gaunard, and J.D. Murphy

Naval Surface Weapons Ctr., White Oak, R-43, Silver Spring, MD 20910, J. Acoust. Soc. Amer., 72 (3), pp 1014-1017 (Sept 1982) 3 figs, 13 refs

**Key Words:** Acoustic scattering, Sound waves

The resonance scattering theory, developed earlier, furnishes poles of the scattering amplitude of acoustic or other types of waves in the complex frequency plane which have been explained in terms of resonances of circumferential waves. Analogous poles in electromagnetic scattering theory were analyzed by the singularity expansion method. It is shown here for the case of sound scattering from an impenetrable sphere that the residue sum over an appropriate subset of

the complex-frequency poles will lead to the synthesis of a given, repeatedly circumnavigating individual circumferential wave (or pulse).

### 83-140

#### Highway Noise Barriers

Transportation Res. Board, Washington, DC, Rept. No. TRB/NCHRP/SYN-87, ISBN-0-309-03310-5, 91 pp (Dec 1981)  
PB82-219411

**Key Words:** Noise barriers, Traffic noise

This synthesis will be of special interest to roadside designers, environmental specialists, and others concerned with the mitigation of excessive highway noise. The experiences of highway agencies in the use of noise barriers are reviewed, and recommendations are offered for reducing the cost of barriers.

### 83-141

#### Evaluation of Noise Barriers

R. Hendriks and M.M. Hatano  
Office of Transportation Lab., California State Dept. of Transportation, Sacramento, CA, Rept. No. TL-604156, FHWA/CA-81/07, 278 pp (June 1981)  
PB82-225889

**Key Words:** Noise reduction, Noise barriers

The FHWA 77-108 and California Department of Transportation Test 703 noise prediction and barrier design models, community attitudes and barrier cost effectiveness were evaluated. Simultaneous noise measurements were taken using up to 10 microphones varying in height and distance behind each barrier. Before and after barrier noise levels were measured at seven barrier sites. At four existing barriers, two sets of measurements were taken, one behind and one adjacent to - and not protected by - the barrier. Traffic was counted simultaneously.

### 83-142

**Handbook of Urban Rail Noise and Vibration Control**  
H.J. Saurenman, J.T. Nelson, and G.P. Wilson  
Wilson, Ihrig and Associates, Inc., Oakland, CA, Rept.

No. UMTA-MA-06-0099-82-1, DOT-TSC-UMTA-81-72, 799 pp (Feb 1982)  
PB82-220757

**Key Words:** Urban noise, Railroad trains, Noise reduction, Vibration control, Manuals and handbooks

This handbook is a guide to the prediction and control of all types of urban rail transit noise, ranging from train noise heard by the community at large to noise in maintenance shops heard only by transit employees. The topics covered include: acceptability criteria for transit related noise and vibration; the general characteristics of urban rail noise and vibration; techniques and equipment for measurement of noise and vibration; control of transit vehicle noise and vibration; control of community noise from surface tracks and aerial structures; prediction and control of groundborne noise and vibration; control of noise in transit stations; control of noise from station ancillary equipment such as air-conditioning systems and fan and vent shafts; control of noise around yards and shops; control of wheel squeal noise; and control of pressure transients in subway tunnels.

### 83-143

#### The Acoustical Structure of Highly Porous Open-Cell Foams

R.F. Lambert

Inst. of Tech., Univ. of Minnesota, Minneapolis, MN 55455, J. Acoust. Soc. Amer., 72 (3), pp 879-887 (Sept 1982) 9 figs, 2 tables, 12 refs

**Key Words:** Foams, Acoustic properties

This work concerns both the theoretical prediction and measurement of structural parameters in open-cell highly porous polyurethane foams. Of particular interest are the dynamic flow resistance, thermal time constant, and mass structure factor and their dependence on frequency and geometry of the cellular structure. The predictions of cell size parameters, static flow resistance, and heat transfer as accounted for by a Nusselt number are compared with measurement.

### 83-144

#### Measurement Techniques and Analysis of Fluid-Borne Noise in Pumps

P.J. McNulty

Fluid Mechanics Div., Natl. Engrg. Lab., East Kilbride, UK, Rept. No. NEL-674, 23 pp (May 1981)  
N82-22504

**Key Words:** Pumps, Fluid-borne noise, Fluid-induced excitation, Cavitation noise, Measurement techniques

The application of noise measuring instrumentation and techniques to the detection of fluid-borne noise, particularly cavitation noise, in pumps is reviewed and noise variation with pump speed and flow rate is considered.

### 83-145

#### **Computer Simulation of Acoustic Intensity in a Rectangular Enclosure**

D. Allen-Booth and G.J. McNulty

Sheffield City Polytechnic, Pond Street, Sheffield S1 1WB, UK, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 287-289, 3 figs, 3 refs

**Key Words:** Enclosures, Acoustic intensity method, Computerized simulation

This paper is concerned with the prediction of omnidirectional sound intensity in an enclosed area. The main feature of the work is the estimation of sound intensity at a receiving point for a given number of reflections. This is highlighted by the fact that for a hard walled enclosure or one of low absorption coefficient the effect of reflection is high. In such a case the number of reflections is computed to indicate the additional sound intensity required. Thus the acoustics of the area can be planned to suit a given requirement.

### 83-146

#### **Propagation of Elastic Surface Waves along a Cylindrical Cavity and Their Excitation by a Point Force**

A. Bostrom and A. Burden

Inst. of Theoretical Physics, S-41296 Goteborg, Sweden, J. Acoust. Soc. Amer., 72 (3), pp 998-1004 (Sept 1982) 16 figs, 11 refs

**Key Words:** Cavities, Cylindrical cavities, Elastic media, Elastic waves, Wave propagation, Point source excitation

The existence of surface wave modes, propagating along an infinite cylindrical cavity in an elastic medium, is established for every integer  $m$ , where  $m$  is the azimuthal mode number. These waves are analogous to the Rayleigh wave on a half-space, being confined to the immediate vicinity of the cavity. The modes exhibit dispersion and have a cutoff frequency which increases with  $m$ , except for the flexural ( $m = 1$ ) mode which exists at all frequencies. At cutoff the

phase velocity is equal to that of the shear waves and decreases, with increasing frequency, to that of the Rayleigh wave. Results are presented for the group velocities and displacement and stress fields of the modes and also exhibit the effect of various point forces acting near the cavity.

### 83-147

#### **Investigation into the Dynamic Behaviour of a Reflection Silencer and an Absorption Silencer (Untersuchungen über das dynamische Verhalten eines Reflexions- und eines Absorptionsschalldämpfers)**

N. Kania and K. Graunke

Inst. f. Kolbenmaschinen, Univ. Hanover, Germany, Forsch. Ingenieurwesen, 48 (3), pp 74-81 (1982) 9 figs, 8 refs  
(In German)

**Key Words:** Blowers, Silencers, Acoustic absorption, Acoustic reflection, Pipes (tubes)

Two silencers differing in design are examined in a Roots blower installation with respect to their operation and effectiveness. A backpressure-free absorption silencer serves as a comparison to determine the behavior of a three-chamber resonant silencer. The values of pressure vibration measurements and their frequency analyses are used to compare the resonant frequencies obtained from the transfer behavior of the resonant silencer with the calculated ones. Any differences found can be explained by the influence of flow in a real system.

### 83-148

#### **Computer Simulation of Sound in Polygonomial Shaped Enclosures**

G.J. McNulty, D. Allen-Booth, R. Gunson, and A. Tanchou

Sheffield City Polytechnic, Pond St., Sheffield S1 1WB, UK, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 357-361, 4 figs, 4 refs

**Key Words:** Enclosures, Computerized simulation, Sound pressure levels

The predicted and experimental investigation of sound pressure levels in an irregular planform area is presented. A feature of the work is the computer mapping of the area and the consideration of images and reflection orders for a given area.

## SHOCK EXCITATION

83-149

**Seismic Safety Margins Research Program. Phase 1  
Final Report: Soil Structure Interaction (Project III)**  
J.J. Johnson, O.R. Maslenikov, J.C. Chen, and R.C. Chun

Lawrence Livermore Natl. Lab., CA, Rept. No. UCRL-53021-VOL-4, 147 pp (June 1982)  
NUREG/CH-2015-V4

**Key Words:** Seismic analysis, Earthquake simulation, Interaction: soil-structure, Substructuring methods

Three objectives of the soil-structures interaction (SSI) project of the Seismic Safety Margins Research Program were to model SSI for system analysis, using state-of-the-art analysis techniques; to identify important parameters in the SSI phenomena through sensitivity studies; and to compare analysis techniques.

83-150

**The Blast Waves from Unconfined Axisymmetric Vapour-Cloud Explosions**

M.S.N. Raju

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 277 pp (1982)  
DA8218543

**Key Words:** Shock waves, Explosions

This dissertation presents a systematic study of the blast waves produced by axisymmetric detonation waves and constant velocity as well as accelerating deflagration waves propagating through homogeneous axisymmetric clouds whose energy density approximate that of a typical hydrocarbon-air mixture. The behavior of the blast wave was studied in a compressible medium surrounding a flammable mixture during and after the propagation of a heat addition wave which models the detonation or deflagration process. In this study the non-steady, two-dimensional fluid dynamic equations of motion were integrated using Godunov's computational scheme subject to appropriate boundary conditions. The actual combustion process was replaced by a simple heat-addition working fluid model.

83-151

**Computer Aided Design of Vibroimpact Stops**

A. Fathi, D.R. Young, and N. Popplewell

Mech. Engrg. Dept., Univ. of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 177-179, 4 figs, 7 refs

**Key Words:** Vibro-impact systems, Computer-aided techniques

The purpose of this paper is to present an efficient algorithm for a desk-top computer which will assess appropriate clearances and stiffnesses of a given number of vibroimpact stops. Problems associated with a user-friendly presentation of the computerized display of the dynamic interactions between the structure and stops is outlined. The methodology is illustrated by considering the example of a reasonably homogeneous and uniform beam colliding with a single stop.

83-152

**Shock Dynamics in Non-Uniform Media**

C.J. Catherasoo

Ph.D. Thesis, California Inst. of Tech., 117 pp (1982)  
DA8218955

**Key Words:** Shock wave propagation

The theory of shock dynamics in two dimensions is reformulated to treat shock propagation in a non-uniform medium. The analysis yields a system of hyperbolic equations with source terms representing the generation of disturbances on the shock wave as it propagates into the fluid non-uniformities. The theory is applied to problems involving the refraction of a plane shock wave at a free plane gaseous interface.

83-153

**Duration of Earthquakes, Comparison Between Ground Motion and Structural Motion**

M.J. O'Rourke, R. Serna, and R.U. Johnson

Dept. of Civil Engrg., Rensselaer Polytechnic Inst., Troy, NY, Rept. No. CE-82-3, NSF/CEE-82016, 72 pp (May 1982)  
PB82-233834

**Key Words:** Ground motion, Earthquake resistant structures, Earthquake response

Several ground motion durations relevant to the behavior of structures during earthquakes are compared. Time periods

are determined for which the relative displacements in structures subjected to earthquake ground motion are largest. The ground motion durations are compared with the time interval during which there is significant seismically induced structural motion. Results are presented of studies of buildings affected by earthquakes in Sendai, Japan and in San Fernando, California.

**83-154**

**Field Measurement of Seismic Wave Velocity and Attenuation for Dynamic Analyses**

R.J. Hoar

Ph.D. Thesis, Univ. of Texas at Austin, 524 pp (1982)  
DA8217880

**Key Words:** Seismic waves, Wave propagation, Wave attenuation, Measurement techniques

Crosshole and downhole seismic testing procedures which can be successfully used for accurate evaluation of in situ shear and compression wave velocities and amplitudes for use in engineering analyses are described. The major emphasis is on measurement of shear wave velocity by the crosshole method because of the importance of shear wave velocity in dynamic analyses and because of the greater accuracy and definition attainable with the crosshole method.

**83-155**

**Effect of Ground Motion Characteristics on the Seismic Response of Torsionally Coupled Elastic Systems**

S.-Y. Kung

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 230 pp (1982)  
DA8218502

**Key Words:** Seismic response, Beams, Elastic properties, Ground motion, Multistory buildings

This study presents a systematic investigation of the effects of ground motion characteristics, especially its multi-directional character, on the response of torsionally coupled elastic structural systems. The ground motion model is probabilistic and is founded on the assumption of the existence of ground motion principal directions. The structural systems considered are single-story and multi-story elastic shear beam models with stiffness eccentricity.

**83-156**

**Jump Phenomenon under Impulsive Force**

Y. Iwata and Y. Kobori

Dept. of Mech. Engrg., Kanazawa Univ., 2-40-20, Kodatsuno, Kanazawa, 920 Japan, Bull. JSME, 25 (205), pp 1120-1126 (July 1982) 6 figs, 5 refs

**Key Words:** Jump phenomenon, Single degree of freedom systems, Mass-spring systems, Vibrating structures, Impact force

The response of a single-degree-of-freedom nonlinear spring-mass system, with the third order displacement term retained, is considered when an impulsive force acts on a vibrating system in steady-state condition. By replacing the impulsive effect with the velocity increment and using the phase plane diagram, the response for the impulse is analyzed. The velocity increment frequently leads to a jump phenomenon in systems with multiple steady states. A method for determining an equivalent velocity increment is developed.

**83-157**

**Noise and Vibration Control for Surface Mines: Program Document**

B.V. Johnson, R.J. Seibel, and D.E. Siskind

Bureau of Mines, Washington, DC, Rept. No. BUM-INES-IC-8876, 15 pp (Apr 1982)  
PB82-220401

**Key Words:** Mines (excavations), Blast effects, Noise reduction, Vibration control

This publication summarizes the in-house and contract research and development projects conducted since 1974 by the Bureau of Mines for the control of noise and vibrations from surface mine blasting.

**VIBRATION EXCITATION**

(Also see No. 151)

**83-158**

**Forced Vibrations in an Unsymmetric Piecewise-Linear System Excited by General Periodic Force Functions (2nd Report, The Analysis up to the 4th Order Superharmonic Resonance by Means of the Method of Convergency Improvement)**

H. Kumano and S. Maezawa

Faculty of Engrg., Metropolitan College of Tech., Tokyo, Japan, Bull. JSME, 25 (206), pp 1289-1298 (Aug 1982) 5 figs, 11 refs

**Key Words:** Forced vibration, Undamped structures, Periodic excitation

Forced vibrations in an unsymmetric piecewise-linear system without damping excited by general periodic force functions are discussed. The main resonance and the superharmonic resonances from the second up to the fourth order are analyzed by a Fourier series method modified by the convergence improvement by means of the series transformation.

**83-159**

**Time-Marching Transonic Flutter Solutions Including Angle-of-Attack Effects**

J.W. Edwards, R.M. Bennett, W. Whitlow, Jr., and D.A. Seidel

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83295, 16 pp (Apr 1982) (Presented at AIAA/ASME/ASCE/AHS Struct., Structural Dyn. and Mater. Conf., New Orleans, May 10-12, 1982) N82-23196

**Key Words:** Flutter, Airfoils, Computer programs

Transonic aeroelastic solutions based upon the transonic small perturbation potential equation were studied. Time-marching transient solutions of plunging and pitching airfoils were analyzed using a complex exponential modal identification technique, and seven alternative integration techniques for the structural equations were evaluated.

**83-160**

**Finite Element Analysis of Large Scale Superconducting Toroidal Field Coil Coupled with Laplace Transform**

M. Uesaka, K. Miya, and F. Moon  
Cornell Univ., Ithaca, NY, ASME Paper No. 82-PVP-51

**Key Words:** Coils, Electromagnetic excitation, Finite element technique, Laplace transformation, Harmonic response

Described are vibration characteristics of large-scale superconducting magnets of INTOR, LCT and NUWMAK de-

signs. The vibration analyzed here is not a usual one, but rigorously coupled with toroidal coil current. The coupling effect of the coil current is represented with the magnetic stiffness, which is dependent on sizes and shapes of the coils and also proportional to the coil current squared. Results of the coupling effect reveal that a squared frequency of harmonic vibration is linearly related to the squared coil current.

## THERMAL EXCITATION

**83-161**

**Distributed Parameter Modeling of a Multi-Concentric Cylindrical Heat Exchanger**

S. Takashima, H. Kanoh, and M. Masubuchi  
Faculty of Education, Kumamoto Univ., 2-40-1 Kurokami, 860 Kumamoto, Japan, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 368-370, 8 figs, 1 table, 2 refs

**Key Words:** Heat exchangers, Cylinders, Concentric structures, Frequency response, Temperature effects, Continuous parameter method

In this paper, a multi-concentric cylindrical heat exchanger is analyzed as a distributed parameter system and the results of its dynamical behavior are presented as frequency responses of the outlet temperature to the change of the inlet temperature. Experimental frequency responses are obtained for this heat exchanger with eleven flow paths and the results of the digital simulation are in good agreement with the experimental ones.

## MECHANICAL PROPERTIES

### DAMPING

(Also see No. 196)

**83-162**

**Fundamental Investigation of an Oil Damper (1st Report - Case of Its Analysis as Steady Flow)**

H. Sekiguchi and T. Asami  
Faculty of Engrg., Himeji Inst. of Tech., 2167, Sho-

sha, Himeji, Hyogo, 671-11 Japan, Bull. JSME, 25 (205), pp 1135-1142 (July 1982) 9 figs, 6 refs

**Key Words:** Dampers, Oil dampers, Damping coefficients

The generating mechanism of a damping force in an oil damper is investigated. Its damping is caused by the oil flow in the annular cross-section clearance between cylinder and piston. A theoretical analysis of damping mechanism is made assuming, for mathematical simplification, that the oil stream is a steady, laminar flow. Various assumptions are set up for this analysis.

### 83-163

#### **Damping Characteristics of Metal Matrix Composites**

N.S. Timmerman

Bolt, Beranek and Newman, Inc., Cambridge, MA, Rept. No. BBN-4864, AMMRC-TR-82-19, 31 pp (Apr 1982)

AD-A114 633

**Key Words:** Composite materials, Damping coefficients

Nine metal matrix composite materials were tested over the frequency range 4 to 10,000 Hz, at room temperature, to determine their damping properties. Cantilever beam samples were measured using both a logarithmic decrement test and a resonant dwell test to cover the entire frequency range.

### 83-164

#### **Shape Characteristics of a Magnetic Damper Consisting of a Rectangular Magnetic Flux and a Rectangular Conductor**

K. Nagaya and H. Kojima

Faculty of Engrg., Gunma Univ., 1-5-1 Tenjin-cho, Kiryu, Gunma-ken, Japan, Bull. JSME, 25 (206), pp 1306-1311 (Aug 1982) 10 figs, 11 refs

**Key Words:** Damping, Electromagnetic properties

Shape characteristics of a magnetic damper consisting of a rectangular magnetic flux and a rectangular conductor are investigated analytically. The optimal shape which gives the largest value of a damping force is clarified. In the analysis the electromagnetic fundamental equations indicated by a potential are solved by the method of the Fourier series expansion procedure, and the expression for obtaining the damping force is derived. The optimal shape of the conductor is obtained as a parameter of the magnetic flux shape by means of the simplex method.

### 83-165

#### **Dynamic Analysis of a Structure with Coulomb Friction**

V.N. Shah and C.B. Gilmore

EG&G Idaho, Inc., Idaho Falls, Idaho, ASME Paper No. 82-PVP-18

**Key Words:** Coulomb friction, Seismic response

A modal superposition method for the dynamic analysis of a structure with Coulomb friction is presented. The finite element method is used to derive the equations of motion, and the nonlinearities due to friction are presented by a pseudoforce vector.

## **FATIGUE**

(Also see Nos. 26, 32, 192, 237)

### 83-166

#### **Fatigue Crack Propagation under Fully Plastic Conditions in an Austenitic Stainless Steel**

G. Baudry, C. Amzallag, J.L. Bernard, and F. Mercier  
Creusot-Loire, Firminy, France, ASME Paper No. 82-PVP-20

**Key Words:** Fatigue (materials), Steel

The objective of this study was to determine the fatigue crack growth rates of small cracks surrounded by large plastic zones in an austenitic stainless steel AISI 316 used in the fabrication of pressurized water reactor components. An experimental program was conducted on different specimen geometries under generalized plastic deformation, in order to obtain an intrinsic material expression of the crack propagation rates.

### 83-167

#### **Environmental Fatigue Crack Growth Analysis Based on Elastic-Plastic Fracture Mechanics**

H.S. Mehta and C. Ranganath

General Electric Co., San Jose, CA, ASME Paper No. 82-PVP-23

**Key Words:** Fatigue (materials), Crack propagation, Pipes (tubes), Steel

Application of the J-integral to prediction of crack growth in carbon steel pipe tests is described. It is shown that the

unusually high crack growth rates observed in the high net section stress tests can be explained on the basis of the elastic-plastic fracture parameter.

83-168

**Fatigue Strength of Corrugated Fin Type Heat Exchanger**

T. Mizoguchi, K. Ueno, K. Okada, and K. Nakaoki  
Kobe Steel, Ltd., Kobe, Japan, ASME Paper No. 82-PVP-29

**Key Words:** Heat exchangers, Fatigue life

In this study, as the first step for reasonable design of the corrugated fin type heat exchanger, the fatigue strength of the core subjected to cyclic loading was investigated from various aspects, such as the studies on the shape of the fin-parting sheet junction, structural analysis, and fatigue tests of actual core and core units. As a result, the stress and deformation behavior occurring in the core were identified, and, although some problems remain to be solved, an effective fatigue design method was developed.

83-169

**Spectrum Method for Equipment Fatigue Evaluation**

W. Wang and A. Chan  
Stone & Webster Engineering Corp., Cherry Hill, NJ,  
ASME Paper No. 82-PVP-31

**Key Words:** Equipment, Fatigue tests, Spectrum analysis

A simple methodology to evaluate fatigue damage on mechanical equipment using the spectrum method of analysis is presented. Conservatism is built into the methodology by controlling the parameters used. The fatigue analysis practice recommended by the ASME formed the basis of this methodology and issues encountered during the implementation stage are discussed.

83-170

**Methods of Estimating Fatigue Life under Complex Loading**

C.-h. Zeng and Y.-s. Wu  
Inst. of Mechanics, Academia Sinica, Acta Mech.  
Solida Sinica, Chinese Soc. Theor. Appl. Mech.,

No. 2, pp 292-300 (1982) 5 figs, 11 refs  
(In Chinese)

**Key Words:** Fatigue life

The nominal stress method of estimating fatigue life is reviewed. Estimation methods of fatigue life under complex loading are described and analyzed in detail. The nominal stress method is compared with local stress-strain methods and some suggestions are given.

83-171

**Nonlinear Aspects of Fatigue Crack Propagation -- A Fracture Mechanics Approach**

E.T. Moyer, Jr.  
Ph.D. Thesis, Lehigh Univ., 174 pp (1982)  
DA8218694

**Key Words:** Fatigue (materials), Crack propagation, Fracture properties

The purpose of this dissertation is to investigate the process of fatigue crack propagation in a material and to delineate the fundamental phenomena associated with observed growth characteristics. The material under investigation is modeled to behave in an elastic-plastic manner under cyclic loading. The stress analyses are performed using a finite element procedure. These elastic-plastic calculations are based on the incremental theory of plasticity with a von Mises yield criterion. Special 1/9th - 4/9th crack tip elements are employed to account for the crack tip stress and strain singularities.

83-172

**Effect of Specimen Thickness on Fatigue Crack Propagation in High Strength Steels**

K. Fujitani, T. Sakai, A. Nakagawa, and T. Tanaka  
Faculty of Science and Engrg., Ritsumeikan Univ.,  
Kyoto, Japan, Bull. JSME, 25 (206), pp 1195-1201  
(Aug 1982) 7 figs, 2 tables, 22 refs

**Key Words:** Fatigue life, Crack propagation, Steel

With particular attention to the effect of the specimen thickness, fatigue crack propagation behavior was experimentally examined on plate specimens of 3-hr. aged and solution-treated maraging steels and of carbon steel S55C. It is concluded that the crack propagation rate tends to decrease with a decrease of the specimen thickness for each

of the materials. Another finding is that the crack opening ratio  $U$  tends to decrease in the crack growth process for the aged maraging steels, but the ratio increases to unity for the carbon steel.

## EXPERIMENTATION

### MEASUREMENT AND ANALYSIS

(Also see Nos. 200, 201, 202, 203, 204, 226, 236)

83-173

#### A Real-Time Digital Signal Analyzer Correlator Averager Power Spectral Density Analyzer

S. Ganesan, G. Gopalrathnam, and M. Renukadevi  
Natl. Aeronautical Lab., Post Bag No. 1779, Bangalore, 560017, India, IEEE Trans., Indus. Electronics, IE-29 (1), p 73 (Feb 1982)

**Key Words:** Signal processing techniques, Spectrum analyzers, Digital techniques, Real time spectrum analyzers

The digital signal analyzer described here computes the values of auto- and cross-correlation functions, recovers signals buried in noise, and computes cross- and auto-power spectral density at 100 equally spaced points on the time-delay axis or frequency axis. The results are presented on an oscilloscope or on an X-Y recorder. The digital technique used, the averaging modes available, the theory of extraction of signal from noise by cross correlation with unit impulses, coarse quantization for input signals, and the technique for obtaining power spectral density from correlation function are discussed.

83-174

#### Spectral Estimation Using Combined Time and Lag Weighting

A.H. Nuttall and C.C. Carter  
U.S. Naval Underwater Systems Ctr., New London, CT 06320, IEEE, Proc., 70 (9), pp 1115-1125 (Sept 1982) 11 figs, 34 refs

**Key Words:** Spectrum analysis, Signal processing techniques

This paper presents a five-step method for spectral estimation that combines time and lag weighting and leads to a procedure

that requires less than one-half the computations of standard methods. The Blackman-Tukey method and the weighted overlapped segment averaging method (widely used in sonar and other applications) are shown to be special cases of the combined method.

83-175

#### The Application of Spectral Estimation Methods to Bearing Estimation Problems

D.H. Johnson  
Dept. of Elec. Engrg., Rice Univ., Houston, TX 77001, IEEE, Proc. 70 (9), pp 1018-1028 (Sept 1982) 7 figs, 45 refs

**Key Words:** Spectrum analysis, Signal processing techniques

The equivalence between the problem of determining the bearing of a radiating source with an array of sensors and the problem of estimating the spectrum of a signal is demonstrated. Modern spectral estimation algorithms are derived within the context of array processing using an algebraic approach. Emphasis is placed on the problem of determining the bearing of a sound source with an array. Special issues encountered in applying these estimates are discussed.

83-176

#### Comb Filters - Simulation and Design

A.T. Kossidas and S.A. Pactitis  
Higher Technical Education College, ASETEM - SELETE, Maroussi, Athens, Greece, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 64-66, 6 figs, 7 refs

**Key Words:** Filters, Digital filters, Simulation, Design techniques

A technique is given for the simulation and implementation of comb filters. An appropriate discrete model of the comb filter is chosen.

83-177

#### Direct Measurement of Acoustical Intensity. Application to Identification of Pressure Pulse Sources in Circuits

A.B. Cassagnet

Centre Technique des Industries Mecaniques, Senlis,  
France, Rept. No. CETIM-11H900, 50 pp (Oct 1981)  
DFMKC82.001

**Key Words:** Acoustic measurement, Acoustic intensity method

A theoretical analysis of the characteristics of a quasi-stationary flat wave; i.e., pressure variations, acoustical intensity, and progressive wave ratio, is given. Characterization is made of a quasi-stationary wave by means of two sensors sensitive to acoustical pressure.

### 83-178

#### **Coping with Vibratory Stress**

J.M. Steele and N.F. Rieger  
Stress Technology, Inc., Rochester, NY, Mach. Des.,  
54 (22), pp 129-134 (Sept 23, 1982) 6 figs

**Key Words:** Vibratory stresses, Stress analysis

Procedures and instrumentation for the determination of vibratory stresses, which contribute significantly to fatigue and machinery failure, are described. The most sophisticated modal analysis systems use a dual-channel analyzer coupled with a microprocessor and graphics display terminal. The microprocessor accumulates a set of transfer functions and converts them into mode shapes, and the output of the system appears identical to that of a finite-element calculation. If the microprocessor has enough computing power, an analytic model can be set up in parallel with the experimental model. The analytic model can then be verified, refined, and used to predict the response of proposed redesigns.

### 83-179

#### **Digital Angular Speed Measurement Using Waveform Sampling**

O.P. Malik, G.S. Hope, and J. James  
Dept. of Engrg., Univ. of Calgary, Calgary, Alberta,  
Canada T2N 1N4, IEEE Trans., Indus. Electronics,  
IE-29 (1), pp 56-66 (Feb 1982) 10 figs, 2 tables,  
15 refs

**Key Words:** Angular speed, Measurement techniques, Digital techniques

A method of digital angular speed measurement based on waveform sampling utilizing an orthogonal pair of sinusoids is proposed. Details of the derivation and implementation

of the technique are described. One of the earlier techniques of speed measurement is compared with the proposed waveform sampling technique by estimating the speed of turbine-generator unit model under steady-state and transient conditions.

### 83-180

#### **The Transient Response of a Square-Law Gate Sampling Oscillographic System Excited by a Step-like Pulse Having Overshoot**

W.-s. Liu and S.-h. Sun  
Harbin Res. Inst. of Electronic Tech., Harbin City,  
China, IEEE Trans., Instrum. Meas., IM-31 (2), pp  
102-104 (June 1982) 2 figs, 2 refs

**Key Words:** Oscilloscopes, Graphical analysis, Transient response

The transient response of a square-law gate sampling oscillographic system excited by a step-like pulse with overshoot is quantitatively analyzed.

### 83-181

#### **The Design of a Programmable Transversal Filter and Its Application in Spectral Analysis**

P. Menard, D. Roy, and R. Inkol  
Interactive Circuits and Systems, Ltd., Ottawa,  
Ontario, Canada, IEEE Trans., Instrum. Meas., IM-31  
(1), pp 21-27 (Mar 1982) 11 figs, 13 refs

**Key Words:** Filters, Transversal filters, Spectrum analysis

This paper discusses the design of programmable transversal filters employing novel mixed analog-digital architectures and their application in spectral analysis. Experimental results confirming these concepts are included.

### 83-182

#### **Shock and Vibration Instrumentation**

R. Plunkett  
Dept. of Aerospace Engrg. and Mech., Univ. of  
Minnesota, 107 Akerman Hall, 110 Union St. S.E.,  
Minneapolis, MN 55455, Shock Vib. Dig., 14 (9), pp  
3-5 (Sept 1982) 15 refs

**Key Words:** Measuring instruments, Vibration measurement, Measurement techniques, Shock response, Reviews

This article reviews the current state of the art of transducers, signal processing methods, and novel methods.

### 83-183

#### **The Use of a Multi-Degree-of-Freedom Dual Balance System to Measure Cross and Cross-Coupling Derivatives**

D.R. Haberman

Arnold Engrg. Dev. Ctr., Arnold AFS, TN, Rept. No. AEDC-TR-81-34, 92 pp (Apr 1982)  
AD-A114 813

**Key Words:** Measuring instruments, Aerodynamic loads

The equations of motion are derived for two existing dual balance systems used to obtain measurements of aerodynamic cross and cross-coupling derivatives. The complete equations of motion presented include the effects of sting motion. Each system incorporates a dynamic cross flexure balance and a five-component static balance. The primary deflection modes of the balances were confirmed using a holographic interferometry measurement technique. Both laboratory and wind tunnel data are presented to illustrate dynamic effects.

### 83-184

#### **Continuous and Discrete Fourier Transforms of Steplike Waveforms**

W.L. Gans and N.S. Nahman

Natl. Bureau of Standards Electromagnetic Tech. Div., Natl. Bureau of Standards, Boulder, CO 80303, IEEE Trans., Instrum. Meas., IM-31 (2), pp 97-101 (June 1982) 4 figs, 7 refs

**Key Words:** Discrete Fourier transform, Spectrum analysis

A steplike waveform which has attained its final value is converted into a duration-limited one which preserves the spectrum of the original waveform and is suitable for discrete Fourier transform computations. The method, which is based upon the response of a time-invariant linear system excited by a rectangular pulse of suitable duration, is first applied to continuous waveforms and then to discrete (sampled) waveforms. For completeness, the difference (error) between the spectra of a continuous waveform and a discrete representation of it are reviewed.

### 83-185

#### **Analysis of Vibration by Component Mode Synthesis Method (Part 2. Forced Vibration (I))**

A. Nagamatsu and M. Ookuma

Industrial Faculty, Tokyo Inst. of Tech., Meguroku, Tokyo, Japan, Bull. JSME, 25 (205), pp 1093-1099 (July 1982) 10 figs, 4 tables, 13 refs

**Key Words:** Component mode synthesis, Forced vibration, Harmonic excitation

A method is presented to analyze the forced vibration of a complex mechanical structure by using the natural modes of its components. The structure is divided into master and branch components. The natural modes of each component are determined separately by the finite element method. The natural modes of all components are synthesized to form generalized system coordinates. The equation of motion under these system coordinates is solved to find the natural frequencies and natural modes. The response of the forced vibration is solved by the modal analysis technique.

### 83-186

#### **Evaluation of Four Subcritical Response Methods for On-Line Prediction Flutter Onset in Wind-Tunnel Tests**

C.L. Ruhlin, J.J. Watson, R.H. Ricketts, and R.V. Doggett, Jr.

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83278, 10 pp (Mar 1982) (Presented at AIAA/ASME/ASCE/AHS 23rd Struct., Structural Dyn. and Mater. Conf., New Orleans, May 10-12, 1982)  
N82-23240

**Key Words:** Flutter, Wind tunnel testing, Turbulence, Testing techniques, Random decrement technique, Power spectral density, Cross spectral method

Methods were evaluated for use in tests where the flutter model is excited solely by airstream turbulence: randomdec, power-spectral-density, peak-hold, and cross-spectrum. The test procedure was to maintain a constant Mach number (M) and increase the dynamic pressure (q) in incremental steps.

### 83-187

#### **Experimental Method to Measure Low Frequency Sound Radiation -- Nearfield Acoustical Holography**

W.Y. Strong, Jr.

Applied Res. Lab., Pennsylvania State Univ., State College, McKeesport, PA, Rept. No. ARL/PSU/TM-82-71, 105 pp (Feb 3, 1982)  
AD-A114 777

**Key Words:** Holographic techniques, Acoustic holography

A technique called Nearfield Acoustical Holography is a significant improvement over conventional holography and is not subject to the wavelength resolution limitation associated with conventional techniques. An exact formulation of the Green's function propagator allows reconstructions of the entire pressure, particle velocity, and vector intensity fields. The vector intensity may be plotted to show the flow of acoustic energy around and away from a source.

**83-188**

#### **Multidimensional Spectral Estimation**

J.H. McClellan

Schlumberger Well Services, Austin, TX, IEEE, Proc., 70 (9), pp 1029-1039 (Sept 1982) 62 refs

**Key Words:** Spectrum analysis, Signal processing techniques

Methods of multidimensional power spectral estimation are reviewed. Seven types of estimators are discussed: Fourier, separable, data extension, MLM, MEM, AR, and Pisarenko estimators. Particular emphasis is given to MEM where current research is quite active. Theoretical developments are reviewed and computational algorithms are discussed.

## **DYNAMIC TESTS**

**83-189**

#### **An Investigation into Methods of Nondestructive Evaluation of Masonry Structures**

J.L. Noland, R.H. Atkinson, and J.C. Baur

Atkinson-Noland and Associates, Inc., Boulder, CO, Rept. No. NSF/CEE-82004, 283 pp (Feb 1982)  
PB82-218074

**Key Words:** Nondestructive tests, Testing techniques, Masonry

Six nondestructive evaluation (NDE) test methods were investigated to assess their potential for strength and condition evaluation of masonry using unmodified commercially available equipment. The methods were: vibration, rebound

hammer, penetration, ultrasonic pulse velocity, mechanical pulse velocity, and acoustic-mechanical pulse. These methods were applied to two-wythe cantilever wall specimens. Companion small-scale specimens, specimens removed from the walls subsequent to the NDE test, and in-the-wall specimens were tested to destruction to provide compression, shear, and flexural strength data for correlation studies.

## **SCALING AND MODELING**

**83-190**

#### **An Evaluation of Scaling Methods for Earthquake Response Spectra**

J.M. Nau

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 350 pp (1982)  
DA8218530

**Key Words:** Scaling, Earthquake response

In current practice, design response spectra are scaled or normalized by the three peak ground motion values - displacement in the low, velocity in the intermediate, and acceleration in the high range of frequencies. In this study, alternative scaling factors are evaluated with the purpose of reducing the dispersion encountered in normalized spectral ordinates. The scaling factors fall into two major groups - one based on ground motion data, and the other, directly on response quantities. Within the group based on ground motion values are the integrals of the squared acceleration, velocity, and displacement, and those quantities derived therefrom, the root-square, mean-square, and root-mean-square motions. Included within the group based on response quantities are the spectrum intensity and the mean Fourier amplitude.

**83-191**

#### **Plastic Models for Structural Analysis: Facts and Fallacies**

R.L. Bannister, I.K. Aneja, and K. Shiraki

Westinghouse Electric Corp., STGD, Lester, PA, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 915-926 (Oct 1982) 10 figs, 1 table, 21 refs

**Key Words:** Scaling

Laboratory and field measurements have shown that scale plastic models can be used to measure static deflections and stress levels natural frequencies, response levels, mode

shapes and the effect of terminating impedance of complex structures before they are built. Tests on a realistic model enable a designer to achieve an optimum design before construction of the full-size structure. Model accuracy requires a dedication to understanding and controlling the variables which can alter the results. Poor model workmanship, misunderstood material properties, improper instrumentation, or inadequate experimental techniques may invalidate a complete testing program, not just alter the expected model accuracy.

## DIAGNOSTICS

83-192

### Identifying Fatigue Crack Growth by Acoustic Emission (AE)

T.J. Holroyd

Rolls-Royce Ltd., Derby, UK, Rept. No. PNR-90075, 6 pp (1981)

N82-22529

**Key Words:** Failure detection, Crack detection, Fatigue (materials), Acoustic emission

The temporal distribution technique, which improves detectability of low crack growth rates in the presence of background noise, is introduced. The effects of correlated and uncorrelated noise are removed from analysis by setting a window which excludes correlated noise peaks from the AE peak studied. The uncorrelated noise is characterized in a region of the stress cycle with no correlated peaks.

## MONITORING

83-193

### Condition Monitoring - How to Establish an Effective Programme

B. Stephenson

IRD Mechanalysis, Plant Engineer (U.K.), 25 (4), pp 23-25 (July/Aug 1981) 10 figs

**Key Words:** Monitoring techniques

Guidance on the practical establishment of vibration-based plant maintenance system is outlined.

# ANALYSIS AND DESIGN

## ANALYTICAL METHODS

83-194

### Determination of Eigenvalues of Dynamical Systems by Symbolic Computation

J.C. Howard

NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-84223, 20 pp (Apr 1982)

N82-23988

**Key Words:** Eigenvalue problems, Computer-aided techniques

A symbolic computation technique for determining the eigenvalues of dynamical systems is described wherein algebraic operations, symbolic differentiation, matrix formulation and inversion, etc., can be performed on a digital computer equipped with a formula-manipulation compiler. An example is included that demonstrates the facility with which the system dynamics matrix and the control distribution matrix from the state space formulation of the equations of motion can be processed to obtain eigenvalue loci as a function of a system parameter.

83-195

### Stochastic Versus Deterministic

G.S. Ladde

Dept. of Mathematics, Univ. of Texas at Arlington, Arlington, TX 76019, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 209-210, 6 refs

**Key Words:** Mathematical models, Random response, Periodic response, Stochastic processes

Estimates for the discussion of stochastic versus deterministic problems in the mathematical modeling of real world dynamic processes are presented.

83-196

### Application and Experimental Determination of Substructure Coupling for Damped Structural Systems

Y.-T. Chung  
Ph.D. Thesis, Univ. of Texas at Austin, 188 pp (1982)  
DA8217837

**Key Words:** Substructuring methods, Damped structures, Viscous damping

A generalized substructure coupling procedure for a complex system with general viscous damping is derived from the Hamiltonian function. The modes are considered to be complex, in general, as opposed to the normal modes in an undamped system which are always real. A first-order differential equation formulation is used in order to permit complex substructure modes to be easily employed. Complex residual attachment modes which result from static approximation of neglected higher modes are derived. A new method which employs incomplete complex normal modes in conjunction with the complex residual attachment modes to account for the contribution of neglected higher order modes is developed. The new method provides the system equations of motion with reduced number of degrees of freedom by using component mode synthesis, while it retains the accuracy of the original system comparable to, or better than, that obtained by purely mode truncation.

**83-197**  
**The Computing of Dynamic Characteristics of Certain Class of Processes Described by Partial Differential Equations**

E. Humo and M. Popovic  
Electrotechnics Faculty, Univ. of Sarajevo, Sarajevo, Yugoslavia, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 1, pp 123-125, 2 figs, 6 refs

**Key Words:** Continuous parameter method, Time-dependent parameters, Finite difference technique, Heat exchangers

The computation of dynamic characteristics of the distributed parameter processes whose variables depend on time and a geometric coordinate is discussed. By means of finite differences the starting partial differential equations of such processes are transferred into series connected multivariable sections with concentrated parameters. The heat exchanger is used as an example. A simple and effective algorithm for this procedure is given.

**83-198**  
**A Method for Eigenvalues of Sparse-Matrices**  
W.H. Yang

Univ. of Michigan, Ann Arbor, MI, ASME Paper No. 82-PVP-63

**Key Words:** Eigenvalue problems

An efficient method for those eigenvalues of a  $\lambda$ -matrix is presented. A simple explicit convergence criterion is given as well as the algorithm and two numerical examples.

**83-199**  
**Method for Minimization of Solution Costs for Transient Dynamic Analysis of Nonlinear Periodic Structures**

J.S. Van Kirk, W.T. Bogard, and L.R. Wood  
Westinghouse Electric Corp., Pittsburgh, PA, ASME Paper No. 82-PVP-19

**Key Words:** Periodic structures, Transient response

Techniques are described for the transient dynamic analysis of nonlinear periodic structures subjected to time history excitations. These techniques consider the special characteristics of periodic structures in conjunction with the pseudoforce approach in numerical integration to reduce computerized solution costs.

**83-200**  
**Lattice Methods for Spectral Estimation**

B. Friedlander  
Systems Control Technology, Inc., Palo Alto, CA 94304, IEEE, Proc., 70 (9), pp 990-1017 (Sept 1982) 22 figs, 23 tables, 58 refs

**Key Words:** Spectrum analysis, Signal processing techniques

Lattice forms provide convenient parametrization of rational spectra of stationary processes. A comprehensive summary of lattice algorithms for estimating spectral parameters of AR, MA, and ARMA processes is presented. It is shown that various well-known spectral estimation techniques can be efficiently computed from lattice parameters. Algorithms are presented for the autocorrelation, pre-windowed, and covariance methods of forming the sample covariance matrix.

**83-201**  
**Spectrum Estimation and Harmonic Analysis**  
D.J. Thomson

Bell Laboratories, Whippany, NJ 07981, IEEE, Proc., 70 (9), pp 1055-1096 (Sept 1982) 30 figs, 362 refs

**Key Words:** Spectrum analysis, Harmonic analysis, Signal processing techniques

In the choice of an estimator for the spectrum of a stationary time series from a finite sample of the process, the problems of bias control and consistency, or smoothing, are dominant. In this paper a new method is presented based on a local eigen-expansion to estimate the spectrum in terms of the solution of an integral equation. Computationally this method is equivalent to using the weighted average of a series of direct-spectrum estimates based on orthogonal data windows (discrete prolate spheroidal sequences) to treat both the bias and smoothing problems.

### 83-202

#### **Spectral Estimation: An Overdetermined Rational Model Equation Approach**

J.A. Cadzow

College of Engrg. and Appl. Sciences, Dept. of Electrical and Computer Engrg., Arizona State Univ., Tempe, AZ 85287, IEEE, Proc., 70 (9), pp 907-939 (Sept 1982) 14 figs, 7 tables, 66 refs

**Key Words:** Spectrum analysis, Signal processing techniques

In seeking rational models of time series, the concept of approximating second-order statistical relationships; i.e., the Yule-Walker equations, is often explicitly or implicitly invoked. The parameters of the hypothesized rational model are typically selected so that these relationships best represent a set of autocorrelation lag estimates computed from time series observations. One of the objectives of this paper is to establish this fundamental approach to the generation of rational models.

### 83-203

#### **Estimation of Frequencies of Multiple Sinusoids: Making Linear Prediction Perform Like Maximum Likelihood**

D.W. Tufts and R. Kumaresan

Dept. of Elec. Engrg., Kelley Hall, Univ. of Rhode Island, Kingston, RI 02881, IEEE, Proc., 70 (9), pp 975-989 (Sept 1982) 14 figs, 52 refs

**Key Words:** Signal processing techniques

The frequency-estimation performance of the forward-backward linear prediction method of Nuttall/Ulrych and Clayton

is significantly improved for short data records and low signal-to-noise ratio by using information about the rank  $M$  of the signal correlation matrix. A source for the improvement is an implied replacement of the usual estimated correlation matrix by a least squares approximation matrix having the lower rank  $M$ . A second, related cause for the improvement is an increase in the order of the prediction filter beyond conventional limits.

### 83-204

#### **Estimation of Structured Covariance Matrices**

J.P. Burg, D.G. Luenberger, and D.L. Wenger

Time and Space Processing, Inc., Santa Clara, CA 95051, IEEE, Proc., 70 (9), pp 963-974 (Sept 1982) 9 figs, 3 refs

**Key Words:** Covariance function

Covariance matrices from stationary time series are Toeplitz. Multichannel and multidimensional processes have covariance matrices of block Toeplitz form. In these cases and many other situations, the actual covariance matrix belongs to a particular subclass of covariance matrices. This paper discusses a method for estimating a covariance matrix of specified structure from vector samples of the random process. The theoretical foundation of the method is to assume that the random process is zero-mean multivariate Gaussian, and to find the maximum-likelihood covariance matrix that has the specified structure. An existence proof is given and the solution is interpreted in terms of a minimum-entropy principle.

## **MODELING TECHNIQUES**

(Also see Nos. 76, 161, 228, 234)

### 83-205

#### **Static and Dynamic Model of the Subsynchronous Converter Cascade**

J. Dente, J. Santana, G. Labbé, F. Lubrique, and B. Maxwell

Universidade Técnica de Lisboa, Spain, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 24-26, 8 figs, 4 refs

**Key Words:** Mathematical models, Transient response, Stability

A global dynamical model of the subsynchronous converter cascade is presented with experimental verifications. The

model can be used directly for transient studies and stability analysis.

**83-206**

**Modeling and Simulation of Distributed-Parameter Mechanical Systems**

M. Koehne

Institut fuer Mechanik und Regelungstechnik, Universitaet Siegen (GH), Paul-Bonatz-Str. 9, D-5900 Diegen 21, F.R. Germany, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 357-361, 8 figs, 16 refs

**Key Words:** Mathematical models, Simulation, Analog simulation, Digital simulation, Continuous parameter method, Flexural vibration, Materials handling equipment

Presented are research activities in the area of modeling and simulation of distributed parameter elastic systems with continuous mass transport, such as the transverse vibration of hauling pipes in ocean mining systems and vibrations of axially moving steel strips in high-speed rolling mills. Both digital and analog simulation methods have been applied to investigate the dynamic behavior of these systems.

**83-207**

**Global Explanation of Internal Forces in Mechanical Systems of Vehicles**

J. Šprinc and O. Kropáč

Inst. of Theoretical and Appl. Mech., Czechoslovak Academy of Sciences, Prague, Czechoslovakia, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 154-156, 4 figs, 7 refs

**Key Words:** Mathematical models, Multidegree of freedom systems, Ground vehicles

Prevailing theories used in Czechoslovakia for the dynamic analysis of multibody systems are outlined. Among such systems are undercarriages of vehicles, elastic hinges of undercarriages, damped suspensions of driving units, automobile passengers, vibrating freight and the like.

**83-208**

**Modelling and Simulation of Actively Controlled Mechanical Systems**

W. Kortum

German Aerospace Res. Establishment (DFVLR), Institute for Flight Systems Dynamics, 8031 Wessling - Oberpfaffenhofen, FRG, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 94-97, 2 figs, 15 refs

**Key Words:** Mathematical models, Active control, Digital simulation, High speed transportation systems, Tracked vehicles

Modern mechanical systems such as high-speed ground transportation vehicles, satellites, robots and other mechanisms are built light-weight and are often equipped with actively controlled actuators. This paper describes how the three modeling areas of rigid-body dynamics, structural dynamics and control systems can be formulated within a complex simulation model for the overall system and be synthesized efficiently within one general purpose digital simulation program. The applicability of this tool is described with emphasis on high-speed tracked vehicles.

**83-209**

**Strain-Rate Effect in Rapid Triaxial Loading of Concrete**

Z.P. Bažant and B.H. Oh

Ctr. for Concrete and Geomaterials, Northwestern Univ., Evanston, IL 60201, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 764-782 (Oct 1982) 6 figs, 64 refs

**Key Words:** Finite element technique, Concretes, Viscoelastic properties

Presented is a generalization of time-independent nonlinear triaxial constitutive relations for concrete to model short-time viscoelastic effects. The effect of strain-rate magnitude upon the initial elastic modulus, the peak stress, and the sharpness of the stress peak is taken into account.

**83-210**

**Practical Applications of Substructuring in Shell Dynamics**

A.D. Sane and J.L. Bitner

Westinghouse Electric Corp., Pittsburgh, PA, ASME Paper No. 82-PVP-65

**Key Words:** Substructuring methods, Finite element techniques, Shells

Advantages and practical aspects of substructuring applied to dynamic analysis of large finite element models is discussed. An application of the substructuring to dynamic analysis of a shell structure is illustrated to highlight the economy, efficiency, and versatility of the method.

## NONLINEAR ANALYSIS

83-211

### An Investigation of Linear and Nonlinear Dynamic Response Utilizing Higher Order Implicit and Unconditionally Stable Explicit Algorithms

A.L. Carter

Ph.D. Thesis, Univ. of Southern California (1982)

**Key Words:** Nonlinear theories, Linear theories, Dynamic response

The solution of dynamic response problems by an unconditionally stable explicit algorithm with a variable time step and higher order implicit algorithms is examined. Higher order implicit integration techniques for solving dynamic response equations are derived utilizing Pade approximations. In an effort to minimize the disadvantages of using these higher order formulas, the conjugate gradient method is employed to solve for the displacements. The accuracy, efficiency, and stability of the techniques are examined for both linear and nonlinear problems.

83-212

### The Analysis of a Nonlinear Difference Equation Occurring in Dynamical Systems

P.G. Reinhall

Ph.D. Thesis, California Inst. of Tech., 108 pp (1982)  
DA8218964

**Key Words:** Nonlinear theories, Difference equations

A difference equation with a cubic nonlinearity is examined. Using a phase plane analysis, both quasi-periodic and chaotically behaving solutions are found. The chaotic behavior is investigated in relation to heteroclinic and homoclinic oscillations of stable and unstable solution manifolds emanating from unstable periodic points. Certain criteria are developed which govern the existence of the stochastic behavior. An approximate solution technique is developed giving expressions for the quasi-periodic solutions close to a stable periodic point and the accuracy of these expressions is investigated. The stability of the solutions is examined and approximate local stability criteria are obtained.

## NUMERICAL METHODS

(Also see No. 221)

83-213

### Numerics for Common First-Passage Problem

P.-T.D. Spanos

Univ. of Texas at Austin, ASCE J. Engrg. Mech. Div., 108 (EM5), pp 864-881 (Oct 1982) 11 figs, 6 tables, 15 refs

**Key Words:** Numerical analysis, Random excitation, Damped structures

Numerical analysis aspects of the Kolmogorov backward partial differential equation which is associated with a classical approximation of the first-passage problem of the response amplitude of a lightly damped linear structure are considered. It is assumed that the structure is excited by a stationary broad-band random process. A formula is presented for the analytical estimation of the eigenvalues of the boundary value problem constructed by a separation of variables procedure on the Kolmogorov equation. The analytical estimates are used as initial values in an iterative scheme which determines the eigenvalues numerically, for several values of the circular barrier of the first-passage problem. An efficient algorithm for the numerical computation of the corresponding eigenfunctions is presented.

83-214

### A Method for Improving Numerical Stability of Implicit Time Integration for Nonlinear Dynamical Structural Response

R.B. Nelson and R. Mak

School of Engrg. and Appl. Science, Univ. of California, Los Angeles, CA 90024, Nucl. Engrg. Des., 20 (1), pp 37-43 (June 1982) 6 figs, 8 refs

**Key Words:** Numerical analysis, Nonlinear response, Elastic-plastic properties, Time integration method

The consequence of unloading is explored under the framework of implicit time integration for elasto-plastic materials. It is shown that simple unloading problems cause numerical failure in the integration scheme due to divergence during equilibrium iteration and that this divergence will occur regardless of time step size. An improved logical scheme is presented which is capable of recognizing when material unloading occurs and suitably modifying the equilibrium iteration scheme. The incorporation of this solution algorithm in conventional implicit time integration schemes for nonlinear finite element structural analysis will significantly improve both the numerical stability and the accuracy of the structural response calculations.

## STATISTICAL METHODS

83-215

### **Time-Domain Approach to the Problem of Sampling**

J. Smejkal

Central Res. Inst., SKODA Plzen, 316 00 Plzen, Czechoslovakia, IEEE Trans., Instrum. Meas., IM-31 (2), pp 105-109 (June 1982) 5 figs, 2 tables, 5 refs

**Key Words:** Statistical analysis, Signal processing techniques, Time domain method

The statistical parameters form a useful base for solving some problems of superposition as well as transmission of random values through linear systems for arbitrary probability distribution. In the present contribution, the approach is extended to characterizing the time-domain signal properties by statistics of differences in a sequence of signal samples. The dependence of standard deviations of the differences on sampling frequency delivers the information for properly choosing the sampling conditions. The influence of linear systems on data smoothing is also investigated.

## PARAMETER IDENTIFICATION

83-216

### **Modeling and Simulation - Valuable Tools of Non-Linear and Adaptive Observer Synthesis**

E. Hasenjaeger and M. Koehne

Institut fuer Mechanik und Regelungstechnik, Universitaet Siegen (GH), D-5900 Siegen 21, Fed. Rep. Germany, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 72-76, 3 figs, 12 refs

**Key Words:** Parameter identification technique, Mathematical models

This paper is concerned with methods of designing state observers for lumped polynomic systems, which can be modeled by state equations with linear, bilinear, and quadratic terms. The general structure of polynomic observers is introduced and simulation serves as a useful tool to determine the final observer parameters.

83-217

### **Testing Various Identification Algorithms for Control**

### **Systems with Stochastically Varying Parameters by a Hybrid Computer**

P. Kopacek

Dept. of Mech. Engrg., Technical Univ. of Vienna, Vienna, Austria, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 69-76, 3 figs

**Key Words:** Parameter identification technique, Random parameters

The aim of this paper is to test and compare various recursive identification and parameter estimation algorithms for systems with stochastically varying parameters with regard to necessary a priori information and the choice of initial values by means of a hybrid computer. Representative for time varying systems a first order lag element with stochastically varying gain and a second order lag element with stochastically varying damping are simulated on the analog part of the hybrid computer. The digital part serves for all other calculations necessary for evaluation.

83-218

### **Random Search Techniques for Optimization of Non-linear Systems with Many Parameters**

G.A. Bekey and S.F. Masri

School of Engrg., Univ. of Southern California, Los Angeles, CA 90007, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 4, pp 225-227, 5 figs, 4 refs

**Key Words:** Parameter identification technique, Optimization, Random search techniques

This paper concerns the application of adaptive random search techniques to large parameter optimization and identification problems. A brief review of the algorithm is presented, followed by a discussion of three examples: identification of 25 unknown parameters in a nonlinear 5-degree of freedom mechanical system, identification of 17 parameters in a nonlinear model of soil mechanics, and determination of optimum values of 24 parameters to obtain a match of two response spectra. The results indicate the robustness and applicability of adaptive random search to a wide variety of nonlinear optimization problems.

83-219

### **Parameter Identifiability for Partial Differential Equations**

C.C. Travis and L.W. White

Health and Safety Res. Div., Oak Ridge Natl. Lab., Oak Ridge, TN 37830, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 2, pp 223-224, 4 refs

**Key Words:** Parameter identification technique

A direct method for determining parameter identifiability of lumped systems has been established. The purpose of this paper is to extend this method to systems described by linear parabolic partial differential equations.

**83-220**

**A Microprocessor-Based System for On-Line Parameter Identification in Continuous Dynamical Systems**

G.P. Rao, D.C. Saha, T.M. Rao, K. Aghoramurthy, and A. Bhaya

Lehrstuhl f. Elektrische Steuerung und Regelung, Ruhr-Universität Bochum, 4630 Bochum, W. Germany, IEEE Trans., Indus. Electronics, IE-29 (3), pp 197-201 (Aug 1982) 6 figs, 7 refs

**Key Words:** Parameter identification technique, Continuous systems, Computer-aided techniques

The paper proposes a microprocessor-based unit for on-line identification of the parameters in linear continuous lumped dynamical systems. The unit implements an algorithm which uses the so-called Poisson moment functionals of input-output data from the actual process under identification.

**83-221**

**Control of Dynamical Systems**

H.T. Banks, J.K. Hale, and E.F. Infante

Lefschetz Ctr. for Dynamical Systems, Brown Univ., Providence, RI, Rept. No. AFOSR-TR-82-0456, 20 pp (Aug 31, 1981)  
AD-A115 287

**Key Words:** Approximation methods, Parameter identification technique

Research is reported on approximation techniques to be employed in parameter identification and optimal control problems. A general theoretical framework for such approximation schemes for partial differential equations was developed and tested numerically for the specific case of model

approximations. Significant advances were made in the difficult problems of parameter estimation for delay systems. Results for both semi-discrete and fully discrete methods for linear equations were obtained.

## OPTIMIZATION TECHNIQUES

(Also see No. 109)

## COMPUTER PROGRAMS

(Also see Nos. 33, 57)

**83-222**

**Dynamic System Coupling (DYSCO) Program. Volume I. User's Manual**

A. Berman

Kaman Aerospace Corp., Bloomfield, CT, Rept. No. R-1649-VOL-1, USAAVRADCOM-TR-81-D-42A, 40 pp (Apr 1982)  
AD-A115 003

**Key Words:** Computer programs, Coupled systems, Helicopters, Rotors

Dynamic System Coupling (DYSCO) is a computer program which allows an interactive user to couple arbitrary components and force algorithms into a model of a helicopter or other dynamic system. The equations of the system may then be solved by a choice of analytical methods. The components available are rigid blade rotor, elastic fuselage, rotor control system, and other structures representable by general linear second-order differential equations. The force methods available are linear rotor loads, tabular rotor aerodynamics with optional induced velocity map, fuselage flat plate drag, and sinusoidal shaker. The solution methods available are time history, linear constant coefficient eigenanalysis, and complex frequency response.

**83-223**

**Dynamic System Coupling (DYSCO) Program. Volume II. Theoretical Manual**

A. Berman

Kaman Aerospace Corp., Bloomfield, CT, Rept. No. R-1649-VOL-2, USAAVRADCOM-TR-81-D-42B, 84 pp (Apr 1982)  
AD-A115 004

**Key Words:** Computer programs, Coupled systems, Helicopters, Rotors

Dynamic System Coupling (DYSCO) is a computer program which allows an interactive user to couple arbitrary components and force algorithms into a model of a helicopter or other dynamic system. The equations of the system may then be solved by a choice of analytical methods. The components available are rigid blade rotor, elastic fuselage, rotor control system, and other structures representable by general linear second-order differential equations. The force methods available are linear rotor loads, tabular rotor aerodynamics with optional induced velocity map, fuselage flat plate drag, and sinusoidal shaker. The solution methods available are time history, linear constant coefficient eigenanalysis, and complex frequency response.

### 83-224

#### **DELIGHT. STRUCT: A Computer Aided Design Environment for Structural Engineering**

R.J. Balling, K.S. Pister, and E. Polak  
Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UCB/EERC-81/19, NSF/CEE-81048, 135 pp (Dec 1981)  
PB82-218496

**Key Words:** Computer programs, Design techniques, Computer-aided techniques

This report describes an expandable software system for optimization-based, interactive computer-aided design of structures. This system can be used for the design of statically and/or dynamically loaded structures which exhibit linear or nonlinear response. The software is the union of an interactive base code for the management of the computer-aided design process named DELIGHT, a dynamic nonlinear general-purpose structural analysis package named ANSR, a library of optimization algorithms specialized for the type of mathematical programming problems characteristic of structural design, and specialized software for the design of seismic-resistant planar steel frames.

### 83-225

#### **Far-Field Acoustic Data for the Texas ASE, Inc. Hush-House**

R.A. Lee  
Air Force Aerospace Med. Res. Lab., Wright-Patterson AFB, OH, Rept. No. AFAMRL-TR-81-148, 287 pp (Apr 1982)  
AD-A114 564

**Key Words:** Computer programs, Aircraft noise, Noise prediction

This report supplements AFAMRL-TR-73-110, which describes the data base NOISEFILE used in the computer program NOISEMAP to predict the community noise exposure resulting from military aircraft operations. The results of field test measurements to define the single-event noise produced on the ground by military aircraft/engines operating in the Texas ASE Inc. hush-house are presented as a function of angle (0 deg to 180 deg from the front of the hush-house) and distance (200 ft to 2500 ft) in various acoustic metrics.

### 83-226

#### **FOURIER: A Frequency-Domain-Analysis Code User Manual**

H.J. Weaver  
Lawrence Livermore Natl. Lab., CA, Rept. No. UCID-19237, 95 pp (Sept 1, 1981)  
DE82006782

**Key Words:** Computer programs, Frequency domain method

The FOURIER code is a semi-interactive FORTRAN IV program which is designed to perform various frequency domain analysis on a function, which may be either real valued or complex. The code is available on both the 7600 and the Cray machines. The function(s) to be analyzed are read into the code via a disk file. The common mode of output is FR80 Graphics files, although the code can also output the data to a disk file. This code has been in use since 1976 and has undergone several modifications and improvements as needed or requested by the users. This report contains a description of both the theory and use of the FOURIER code as well as several example runs.

### 83-227

#### **SEAPLT: A Graphics Post-Processor for the SEADYN Program**

R.L. Webster  
Brigham City, UT, Rept. No. NCEL-CR-82.016, 14 pp (Apr 1982)  
AD-A114 961

**Key Words:** Computer programs, Cables

This report describes the computer programs SEAPLT, which is a graphics post-processor to the general purpose cable dynamics computer model SEADYN. The program is written with CALCOMP compatibility for use with the CDC-Cybernet program UNIPLOT.

83-228

**Modeling and Simulation of Complex Machine Systems in an Integrated Manner**

R.C. Rosenberg

Dept. of Mech. Engrg., Michigan State Univ., East Lansing, MI 48824, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 402-404, 6 figs, 9 refs

**Key Words:** Computer programs, Bond graph technique, Mathematical models

Complex, large-scale machinery systems typically require the modeling of both distributed- and lumped-parameter subsystems in various energy domains. The UNISYS program uses a bond-graph-based approach that allows finite element, transfer function, and bond graph descriptions of both linear and nonlinear subsystems. The project objectives and the program design are discussed.

83-229

**Optimization of the Mechanics and the Control of Elastic Systems with DISCOS**

H.B. Kuntze and H. Bolle

Fraunhofer-Institut f. Informations- und Datenverarbeitung (IITB) D-7500 Karlsruhe, Fed. Rep. Germany, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 84-87, 9 figs, 1 table, 6 refs

**Key Words:** Computer programs, Digital simulation, Automatic control, Nonlinear systems

The paper presents an efficient digital simulation system (DISCOS) which is a helpful tool especially for the analysis and design of automatic control problems with high order and numerous nonlinearities. Its properties are demonstrated by an example which deals with the microcomputer control of a nonlinear high order mass-spring system.

83-230

**Interactive Dynamic Network Analysis**

K.H. Mian

Elecnor, S.A., Bilbao-11, Spain, System Simulation and Scientific Computation, Proc. of the 10th IMACS

World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, pp 117-119, 4 figs, 7 refs

**Key Words:** Computer programs, Network analysis theory

The Interactive Dynamic Network Analysis (IDNA) program presented in this paper simulates the time-response of a multi-machine power system for the solution of system dynamic and control problems. Interactively, the program permits problem definition, modeling of transfer functions of turbines and unit automatic control equipment and network configuration. The simulation calculations are performed by solving the machine and net work performance equations simultaneously.

83-231

**Accuracy and Sensitivity of CRASH**

R.A. Smith and J.T. Noga

National Highway Traffic Safety Admn., Washington, DC, Rept. No. DOT-HS-806 152, 79 pp (Mar 1982) PB82-229410

**Key Words:** Computer programs, Collision research (automotive)

The accuracy and sensitivity of the CRASH computer program in computing delta-V are examined. Accuracy is related to how well CRASH performs in comparison with results from 53 independent staged collisions.

83-232

**Vibration Analysis of Coupled Fluid-Structure Systems: A Convenient Computational Approach**

L. Brusa, R. Ciacci, and A. Greco

CISE (Centro Informazioni Studi Esperienze), Postal Box 12081, Milano, Italy, Nucl. Engrg. Des., 70 (1), pp 101-106 (June 1982) 1 fig, 1 table, 4 refs

**Key Words:** Interaction: structure-fluid, Computer programs

The mathematical model implemented in the ZERO code for dynamic analysis of thin axis-symmetric structures coupled with fluid is briefly described. The numerical experimentation presented is aimed at evaluating the efficiency of the method applied for computation of vibration characteristics of the coupled system.

83-233

**Program for Narrow-Band Analysis of Aircraft Flyover Noise Using Ensemble Averaging Techniques**

D. Gridley

Kentron International, Inc., Hampton, VA, Rept. No. NASA-CR-165867, 70 pp (Mar 1982)  
N82-22949

**Key Words:** Aircraft noise, Noise analyzers, Computer programs

A package of computer programs was developed for analyzing acoustic data from an aircraft flyover. Measured layered meteorological data obtained during the flyovers are used to compute propagation effects through the atmosphere. Final results are narrow-band spectra and directivities corrected for the flight environment to an equivalent static condition at a specified radius.

## GENERAL TOPICS

### CONFERENCE PROCEEDINGS

83-234

**IMACS World Congress on System Simulation and Scientific Computation**

Proceedings of the 10th, Aug 8-13, 1982, Montreal, Canada

**Key Words:** Mathematical models, Simulation, Nuclear power plants, Stochastic processes, Proceedings

Papers presented at this conference were published in five volumes. In volume one the papers are grouped as follows: Numerical Methods for Scientific Computation; Computers and Computer Arithmetics for Scientific Computation; Languages and Codes for Continuous Systems. Volume two contains: Analog/Hybrid Computation; Simulators; Discrete Systems Simulation; Modeling and Simulation in Bio and Environmental Sciences. Volume three: Modeling and Simulation in Engineering; Modeling and Simulation -- General. Volume four: Modeling and Simulation of Energy Systems; SCS Sessions (Society for Computer Simulation); Modeling and Simulation of Computer Performance and Stochastic Systems; Volume 5: late papers. Individual pertinent papers are abstracted in the appropriate sections of this issue of the Digest.

### TUTORIALS AND REVIEWS

83-235

**Future Computer Applications in Acoustics and Vibrations**

N. Popplewell

Dept. of Mech. Engrg., Univ. of Manitoba, Winnipeg, Canada R3T 2N2, System Simulation and Scientific Computation, Proc. of the 10th IMACS World Congress, Aug 8-13, 1982, Montreal, Canada, Vol. 3, p 170, 1 ref

**Key Words:** Computer-aided techniques

Several personal views are stated regarding the present and projected short-term applications of computers in acoustics and vibrations. Advances in computer systems will reinforce the need for complementary analytical approximations and better engineering knowledge of important parameters like damping.

83-236

**A Historical Perspective of Spectrum Estimation**

E.A. Robinson

Dept. of Theoretical and Appl. Mech. and Dept. of Geological Sciences, Cornell Univ., Ithaca, NY 14853, IEEE, Proc., 70 (9), pp 885-907 (Sept 1982) 101 refs

**Key Words:** Spectrum analysis, Signal processing techniques, Reviews

A historical perspective of spectral estimation is presented. To these statistical contributions must be added the equally important engineering contributions to empirical spectrum analysis, which are not treated at all in this paper, but form the subject matter of the other papers in this special issue.

### CRITERIA, STANDARDS, AND SPECIFICATIONS

83-237

**Prediction of Fatigue at Multiaxial Stress -- How Good is the Criterion of the ASME Code?**

J.O. Nokleby and A.O. Waloen

Det Norske Veritas, Oslo, Norway, ASME Paper No. 82-PVP-50

**Key Words:** Standards and codes, Fatigue life, Prediction techniques

*Based on an extensive study of criteria for prediction of fatigue under multiaxial stress conditions, the criterion used by the ASME Pressure Vessel Code has been critically reviewed. It is found that the predictions of this criterion can be seriously in error for certain stress situations.*

## **BIBLIOGRAPHIES**

(Also see Nos. 65, 138)

**83-238**

**Vibrational Analysis of Fluids, 1970 - July, 1982  
(Citations from the NTIS Data Base)**

NTIS, Springfield, VA, 122 pp (July 1982)

PB82-869744

**Key Words:** Fluids, Vibration analysis, Bibliographies

*This bibliography contains citations concerning the vibrational responses of fluids. Fatigue, stress, and the mechanical responses of fluids are considered. Applications in mechanical engineering, hydrodynamics, hydraulics, aerodynamics, and nuclear technology are presented. Mathematical modeling to aid computer simulation and analysis of fluid dynamics are discussed.*

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# CALENDAR

## FEBRUARY 1983

- 28 - SAE Congress & Exposition [SAE] Detroit, MI  
Mar 4 (SAE Hqs.)

## MARCH 1983

- 21-23 NOISE-CON 83 [Institute of Noise Control Engineering] Cambridge, MA (*NOISE-CON 83, Massachusetts Inst. of Tech., Inst. Information Services, 77 Massachusetts Ave., Cambridge, MA 02139 - (617) 253-1703*)
- 28-31 Design Engineering Conference and Show [ASME] Chicago, IL (ASME Hqs.)

## APRIL 1983

- 18-20 Materials Conference [ASME] Albany, NY (ASME Hqs.)
- 18-21 Institute of Environmental Sciences' 29th Annual Technical Meeting [IES] Los Angeles, CA (*IES, 940 E. Northwest Highway, Mount Prospect, IL 60056 - (312) 255-1561*)
- 19-21 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Houston, TX (*Ronald L. Eshleman, Director, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254*)
- 21-22 14th Annual Modeling and Simulation Conference [Univ. of Pittsburgh] Pittsburgh, PA (*William G. Vogt, Modeling and Simulation Conf., 348 Benedum Engineering Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261*)

## MAY 1983

- 9-13 Acoustical Society of America, Spring Meeting [ASA] Cincinnati, OH (ASA Hqs.)
- 9-13 Symposium on Interaction of Non-Nuclear Munitions with Structures [U.S. Air Force] Colorado Springs, CO (*Dr. C.A. Ross, P.O. Box 1918, Eglin AFB, Florida 32542 - (904) 822-5514*)
- 17-19 Fifth Metal Matrix Composites Technology Conference [Office of the Undersecretary of Defense for Research and Engineering] Naval Surface Weapons Center, Silver Spring, MD (*MMCIAC - Kaman Tempo, P.O. Drawer QQ, Santa Barbara, CA 93102 - (805) 963-6455/6497*)

## JUNE 1983

- 6-10 Passenger Car Meeting [SAE] Dearborn, MI (SAE Hqs.)
- 20-22 Applied Mechanics, Bioengineering & Fluids Engineering Conference [ASME] Houston, TX (ASME Hqs.)

## JULY 1983

- 11-13 13th Intersociety Conference on Environmental Systems [SAE] San Francisco, CA (SAE Hqs.)

## AUGUST 1983

- 8-11 Computer Engineering Conference and Exh [ASME] Chicago, IL (ASME Hqs.)
- 8-11 West Coast International Meeting [SAE] Vancouver, B.C. (SAE Hqs.)

## SEPTEMBER 1983

- 11-13 Petroleum Workshop and Conference [ASME] Tulsa, OK (ASME Hqs.)
- 11-14 Design Engineering Technical Conference [ASME] Dearborn, MI (ASME Hqs.)
- 12-15 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI (SAE Hqs.)
- 14-16 International Symposium on Structural Crashworthiness [University of Liverpool] Liverpool, UK (*Prof. Norman Jones, Dept. of Mech. Engrg., The Univ. of Liverpool, P.O. Box 147, Liverpool L69 3BX, England*)
- 25-29 Power Generation Conference [ASME] Indianapolis, IN (ASME Hqs.)

## OCTOBER 1983

- 17-19 Stapp Car Crash Conference [SAE] San Diego, CA (SAE Hqs.)
- 17-20 Lubrication Conference [ASME] Hartford, CT (ASME Hqs.)
- 18-20 54th Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Pasadena, CA (*Mr. Henry C. Pusey, Director, SVIC, Naval Research Lab., Code 5804, Washington, DC 20375*)

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ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203	SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375
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